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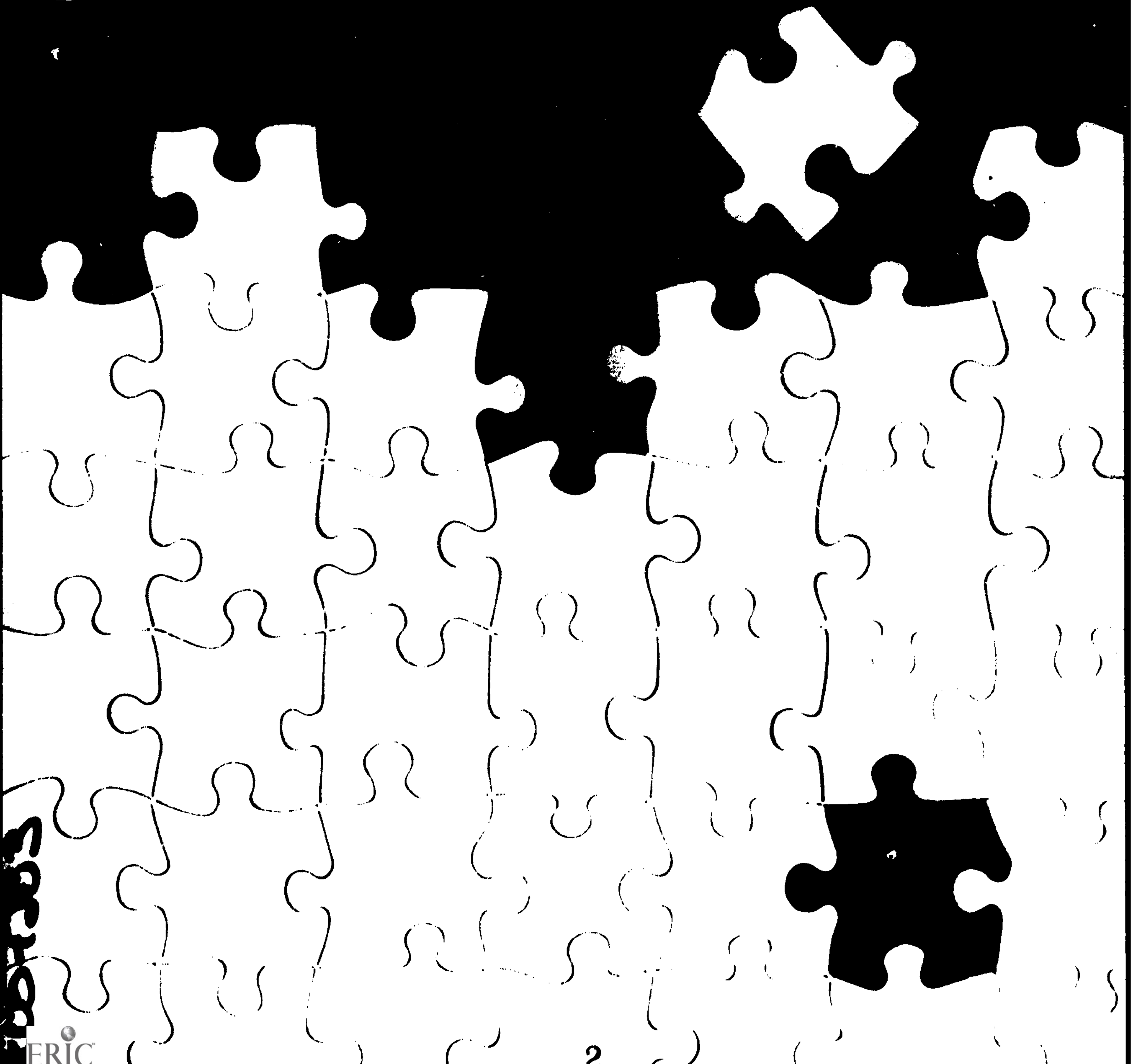
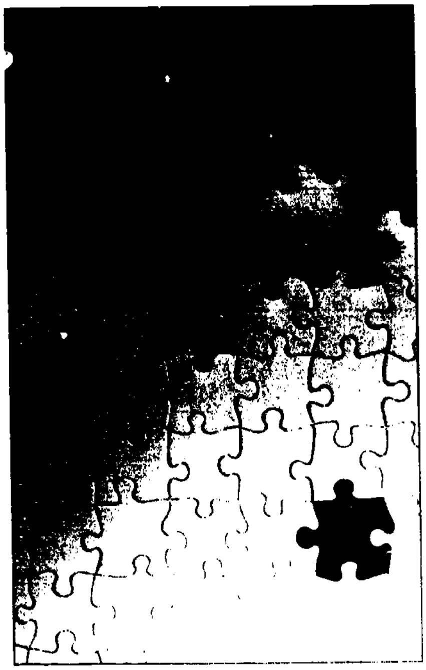
ABSTRACT

"Exploring" is a magazine of science, art, and human perception, produced by Exploratorium in collaboration with other participating museums. This issue focuses on puzzles and problem solving. Brain teasers, puzzles, and the strategies for solving them are included. Features include: (1) "Homework Assignment #3" (Paul Doherty); (2) "The Case of the Smoking Brain" (Ellen Klages); (3) "A Dialogue of Questions" (Adam Frank); and (4) "The Problem Solvers" (Robert Pincus; Pat Murphy; and David Barker). (JRH)

Exploring
Puzzles & Problems





Exploring

Vol. 17, No. 2, Summer 1993

Exploring is a magazine of science, art, and human perception, produced by the Exploratorium in collaboration with other participating museums. *Exploring* communicates ideas that museum exhibits can't easily demonstrate, extending museums beyond their physical walls. Each issue concentrates on a single topic, examining it from a variety of viewpoints. This focus allows us to investigate and discuss interconnections between apparently unrelated phenomena, revealing the essential unity of nature.

Exploring is sent quarterly to the members and contributors of participating museums.

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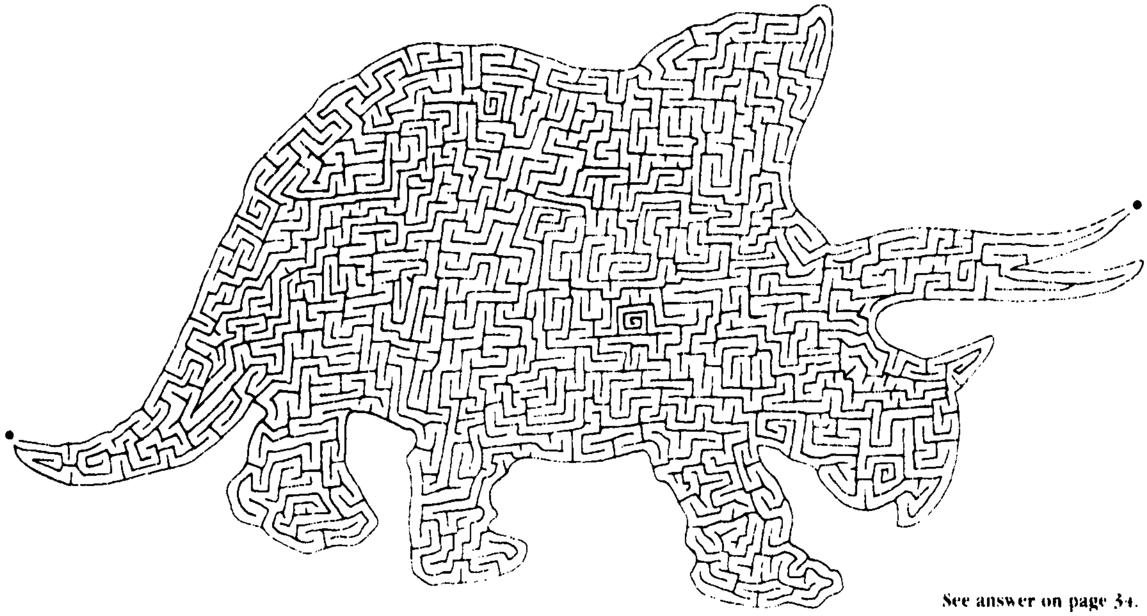
BE CAREFUL! The experiments in this publication were designed with safety in mind. [illegible] when mishandled or misused. Use common sense whenever you're exploring or experimenting.



See answer on page 34.

Puzzles & Problems

To Do & Notice

Features

Departments

Pat Murphy

a House of Cards

Pat Murphy, author of The Falling Woman, The City, Not Long After, *and* Points of Departure, *finds inspiration in a deck of cards. You can get your own* Oblique Strategies, *see page 35 for ordering information.*

When I'm not editing *Exploring* magazine or writing for the Exploratorium, I write novels. When I first began writing fiction, I regarded the process as slightly mysterious, a higher calling, requiring inspiration and the touch of the muse. When I couldn't figure out what to do with a story, I was stuck. I had to wait for inspiration to strike.

But over the years, I've found that inspiration sometimes needs prompting. These days, when I get stuck in the creative process, I pull out a problem-solving tool: a deck of cards called *Oblique Strategies. Over one hundred worthwhile dilemmas.*

On each card, there's a sentence, a phrase, or sometimes a single word. I choose a card from the deck and read the message. "Mine has two sides," says one card. "Be less critical more often," counsels another. "What mistakes did you make last time?" asks a third. [illegible] a fourth.

Cryptic. Subject to interpretation. Truly oblique. But I find that the advice they offer often provides a new approach to the dilemma at hand.

Composer Brian Eno and painter Peter Schmidt developed these "oblique strategies" over many years of creative work. While still in art school, Eno began formulating suggestions that provided new perspectives on his work, reminding him of his creative options and generally keeping him from getting bogged down. When he learned that Schmidt had been doing the same thing, they compared notes and found that many of their suggestions were virtually identical. Together, they produced this deck of cards.

The instructions that came with the deck suggest two ways to use the cards. You can review the entire deck every now and then to remind yourself of creative alternatives. Or you can do as I do: draw a single card from the shuffled pack when you encounter a dilemma. When you draw a card, the instructions advise, "the card is trusted even if its appropriateness is quite unclear."

Sometimes, I find this last instruction difficult to follow — but I think it's important. *Oblique Strategies* offer advice that I must interpret, and it's partly in that interpretation that their power lies. The answer isn't in the cards; it's in me. I know the solution to my problem, but I don't know that I know it.

The cards of *Oblique Strategies* shake me loose from old ways of thinking by forcing me to examine my own knowledge. Sometimes, they offer back-handed assurance that gives me the strength to continue: "You don't have to be ashamed of using your own ideas" or "Just carry on" or simply "Courage!" Sometimes the cards throw a monkey wrench into the works by telling me something that I don't want to hear: "Honor thy error as a hidden intention," or "Look closely at the most embarrassing details and amplify them." But whatever they say, the cards always require a mental stretch — the first step in finding a solution.

I use *Oblique Strategies* for solving creative problems, but others have used them in different contexts. In *Opal Information*, a small magazine published by the producers of *Oblique Strategies*, Ian Stonehouse, a British user of the cards, wrote of a burglary at his home. The burglar had opened Stonehouse's deck of *Oblique Strategies* and, while looking through them, had left a clear thumbprint on the back of a card. Stonehouse took the cards to the police station and the thumbprint was part of the evidence used to convict the burglar. However, it took Stonehouse some time to get his cards back. When I eventually got my *Oblique Strategies* back, the detective constable handed them over and apologized for the delay in returning them. He said all the blokes in his office had spent a lot of time reading them and that it had helped to solve a lot of personal problems and other things. He said they were considering getting a set. ❑

and continue with
consistency
Do we need holes?
Give way to your worst
Instrument roles

Pat Murphy

HELP! Th

YOUR SON WON'T CLEAN HIS ROOM and your mother is coming to visit. You're staring at a page filled with puzzles without a clue about how to begin, and you're starting to feel a little anxious. The pig is in the garden, eating all your flowers. If it's not one thing, it's another. You've got a problem. So how do you go about solving it?

You might think that your approach depends on the problem—and to some extent that's true. But no matter what your problem is, chances are you go through certain steps on your way to a solution. First, you have to understand your current situation (the pig is in the garden) and figure out your goal (getting the pig out of the garden). Then you need to devise a plan for solving the problem (grab a stick and chase the pig out of the garden). Finally, you need to execute your plan and check the results (is the pig really out of the garden?)

The steps seem simple enough, but identifying them can be crucial. Suppose your first attempt at a solution fails: the pig ignores you and your stick. What do you do? It's possible that the flaw is in your execution: perhaps you need a bigger stick to get the pig's attention. You get a bigger stick and try again, and maybe you succeed. But maybe not.

That's where many of us get stuck in problem solving. As psychologist Abraham Maslow pointed out, if the only tool you have is a hammer, you tend to treat everything like a nail. Once you've decided on an approach, you get stuck: even if it doesn't work, you try the same approach again and again. But by returning to the basic steps, you can evaluate your problem solving process and possibly find another approach. You might decide on a different plan: lure the pig out with a bucket of pig chow. Or you could go back one more step and reevaluate your goal: rather than removing the pig from the garden, you decide to plant only flowers that pigs won't eat.

Psychologists who study problem solving have identified a number of strategies that can help people find new approaches to a problem. These strategies are called *heuristics*. The word heuristic comes from the same Greek root as "Eureka!" (I've found it!). Both words come from *heuriskin*, which means "serving to discover."

Basically, a heuristic is a procedure or an approach that's likely to help you solve a problem. Using a heuristic doesn't guarantee that you'll find an answer, but it's likely to help you on your way to a solution. One heuristic, for example, suggests that you question your assumptions. Suppose I asked you to cut a cake into eight equal pieces using only three straight cuts. At first, that might seem like a difficult task. But if you question your assumption, you may come up with the answer. There's more than one way to slice a cake. Are you assuming that people always cut cakes from the top down? If you are, think about other ways to slice a cake, and see if that helps you find a solution.

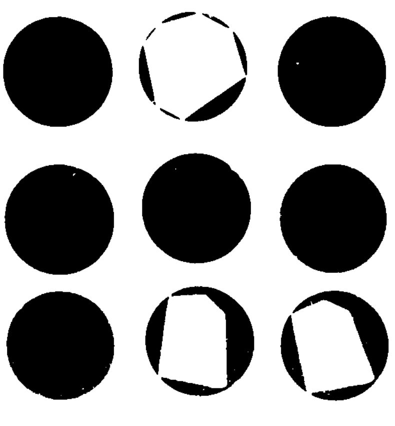
On the following pages are a number of heuristics — along with a number of problems and puzzles. The heuristics come from a variety of sources, but I've found that each of them can help me get unstuck when I run out of approaches to a problem.

Read the heuristics and try to apply them to the problems that follow. As you work, take the time to think about how you go about finding a solution. What strategies do you use? What steps do you take?

If you get stumped, read the heuristic again and try rethinking your approach. For some problems, we've provided hints and suggestions that may help you apply the heuristic.

Some of the problems are easy, some are very hard. You might want to try working with a friend. Often, another person provides a different approach or set of skills. And, by the way, that bit of advice is also a heuristic: if you can't solve a problem, get some help. Take it slowly — if you hit a brick wall, take a break and see if you can find another approach later. You may find that solving one problem gives you insight into another.

Good luck. The answers are on page 33.

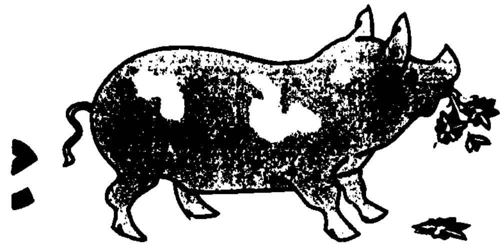


Dot to Dot

Connect these nine dots by using only four straight lines.

Hints and Suggestions

Most people try to solve this problem by drawing lines that stay within the confines of the group of dots. Let your lines extend beyond the group of dots and see if that makes a solution easier.



is in the Garden!

Check your assumptions.

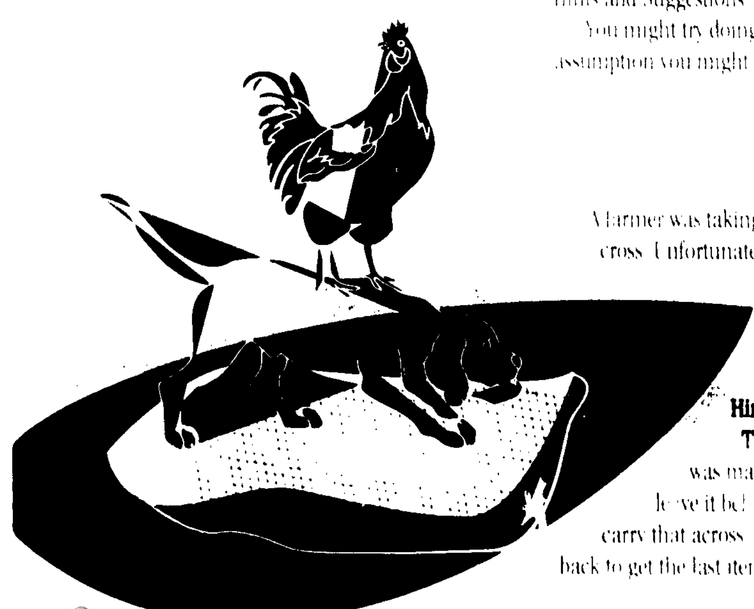
Before you start work on these problems, ask yourself whether you are making implicit assumptions about the solutions. Your unconscious assumptions may limit your ability to solve a problem.

A Glass of Water

Six normal drinking glasses are standing in a row. The first three are full of water, the next three are empty. By handling only one glass, change the arrangement so that no full glass is next to another full glass and no empty glass is next to another empty glass.

Hints and Suggestions

You might try doing this one with six actual glasses. Using real materials may make you aware of an assumption you might otherwise overlook.



Crossing the River

A farmer was taking his dog, a chicken, and a sack of grain to market. He came to a river that he had to cross. Unfortunately, the rowboat would only hold himself and one of his possessions. He can't leave the dog alone with the chicken or the dog will eat the chicken. He can't leave the chicken alone with the grain or the chicken will eat the grain. How does he get all his possessions across the river?

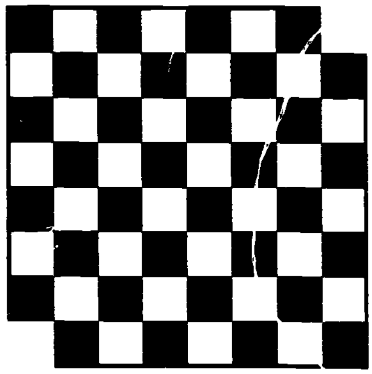
Hints and Suggestions

This type of problem used to drive me crazy— until I realized the basic assumption I was making. Obviously, the first move is to take the chicken across the river, since you can't leave it behind with the dog or the grain. Then you go back and get the dog or the grain and carry that across. But you can't leave the chicken alone with either the dog or the grain while you go back to get the last item, so you're stuck. Or are you? Are you making the same assumption I made?

Think before you act.

Before you try to solve these problems, consider them carefully and try to get a total picture. You may come up with a strategy that limits the possibilities you must explore.

Dominos on a Checkerboard

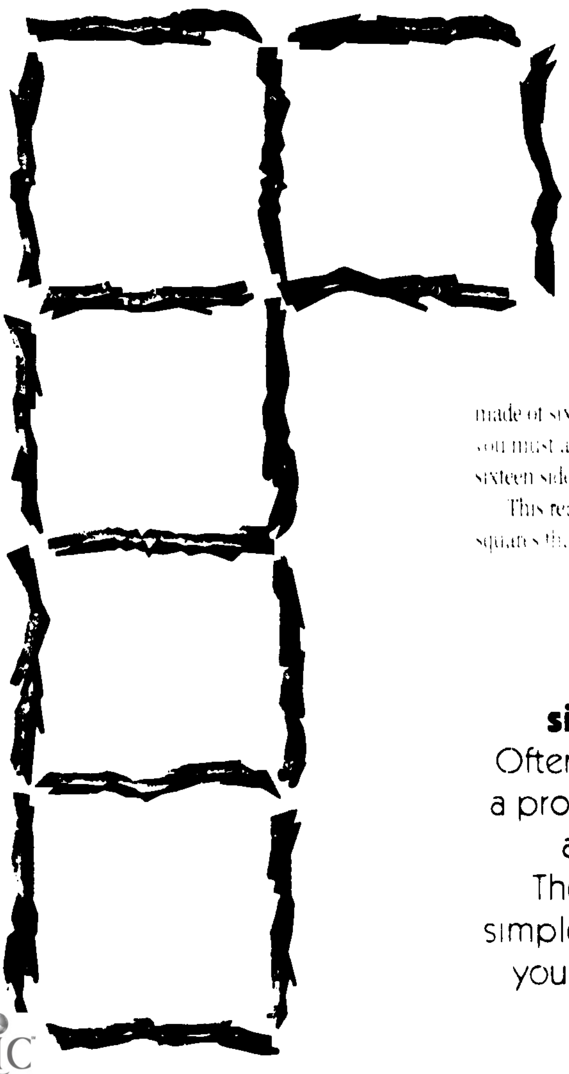


Imagine an ordinary checkerboard with the usual sixty-four black-and-white squares. Suppose two squares have been cut away from the board, one from each of two diagonally opposite corners. It doesn't matter which two corners.

Now imagine that you have thirty-one dominos, each of which will cover exactly two squares of the checkerboard. Can you arrange the dominos so that they cover all sixty-two squares?

Hints and Suggestions:

You can approach this using a trial-and-error method, mentally eliminating the squares on the board two at a time. But you don't have to go to all that trouble. Instead, consider what happens when you lay a domino on the checkerboard. It covers two squares that are side by side. Is there anything notable about the squares that are side by side? What about the squares that have been cut away?



Stick Squares

Suppose you have sixteen sticks arranged in five squares. By moving just three sticks, make four squares. You must use all sixteen sticks.

Hints and Suggestions:

If you're like me, your first impulse will be to start shuffling sticks around and muttering "No, that doesn't work. Neither does that." This approach is an example of trial-and-error problem solving. You can solve the problem with this method, but there's a quicker way.

Stop for a moment and think about the problem. If you were going to make five separate squares with no shared sides, you'd need twenty sticks. Since you start with five squares made of sixteen sticks, some squares share a common side. To make four squares with your sixteen sticks, you must arrange them so that each stick forms the side of only one square. Four squares have a total of sixteen sides.

This reasoning limits the sorts of combinations you try. You know that you want an arrangement of squares that don't have adjoining sides. Now try the problem again.

Consider a simpler model.

Often, you can simplify a problem by looking at a special case. The solution to the simpler version may help you solve the original problem.

The Racquetball Tournament

Suppose you are running a racquetball tournament for 205 players. This is a single elimination tournament—when a player loses, he or she drops out of the tournament. Assuming that you need one scorecard for each match, how many scorecards will you need?

Hints and Suggestions:

How many scorecards would you need for a tournament with three players? How about a tournament with five players?

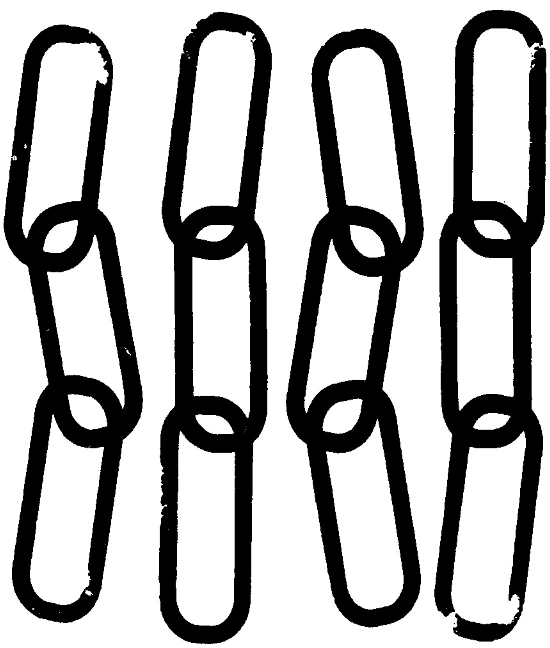
Draw a picture.
Drawing a picture, a diagram, a graph, or a sketch can often help you gain a better understanding of a problem. This understanding may lead you to a solution.

Chain Links

Suppose you have four chains, each three links long. You want to join the four chains into a single chain that forms a circle. Having a link opened costs two cents and having a link closed costs three cents. You only have fifteen cents to spend. How do you do it?

Hints and Suggestions:

Once you've opened a link, you can take it off its original chain of three. Draw a picture in which you take an open link off its chain. Does this suggest a different approach?



Mountain-Climbing Monk

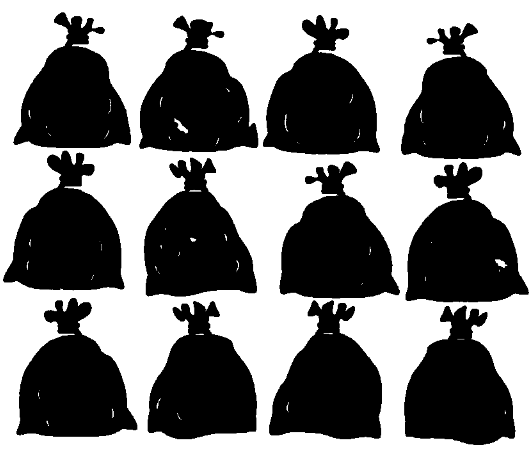
One morning at sunrise, a monk began to climb a mountain. He followed a narrow path that spiraled around the mountain to a temple at the top. The monk ascended slowly, stopping often to rest. He reached the temple just before sunset. The next day, at sunrise, he started his journey back, following the same path. He traveled more quickly than before. Is there a spot along the path that the monk occupies on both trips at precisely the same time of day?

Hints and Suggestions:

People often approach this problem mathematically, trying to calculate when the monk would be where. The simplest solution takes the form of a graph. Try graphing the time of day against the monk's position on the mountain.

Break the problem into smaller pieces.
If a problem is unmanageable, try breaking it into smaller parts. If those parts are still unmanageable, break them into even smaller parts, continuing in this fashion until you arrive at problems of a manageable size.

Sacks of Gold



You have twelve sacks of gold and you know that one of the sacks is either heavier or lighter than the others. You have a balance scale that can hold as many sacks as you like on each side of the scale. You can use the scale only four times. How can you identify the odd sack of gold and figure out whether it's heavier or lighter?

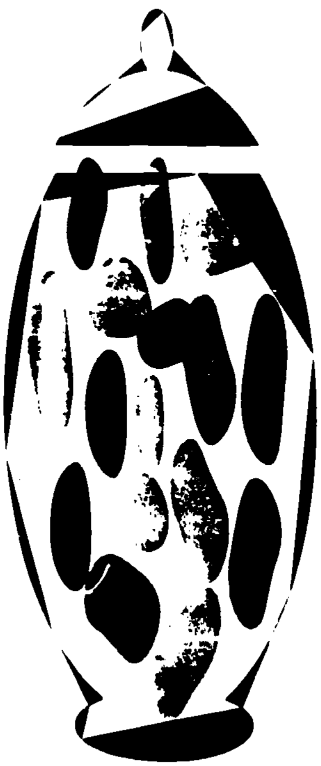
Hints and Suggestions

Most people start by putting six sacks on either side of the balance. Suppose you do that. What do you learn from that weighing? Because one sack is either heavier or lighter, balancing six against six will tell you only that the two groups weigh different amounts—it won't tell you which one has the odd sack.

Somehow, you need to establish that some of the sacks are the standard weight—which will help you figure out which one is not standard. Start with smaller groups—and proceed step by step. This is a tough one—it may take a while. Be patient.

Test various possibilities.

You can solve some problems by proposing hypotheses and working out the consequences of those hypotheses.



Land of Liars

You are visiting a country in which there are two kinds of people: ones who always tell the truth and ones who always lie. You meet two men and you ask, "Are you truthtellers or liars?" One mumbles something and the other says, "He says he's a truthteller. He's a truthteller and so am I." Do you believe him?

Hints and Suggestions

Suppose both men were liars. What would they say? What if the first one were a liar and the second a truthteller?

Full of Beans

Suppose I have two jars filled with jellybeans. One contains red jellybeans and the other contains an identical number of black jellybeans. I take five red jellybeans from the red jellybean jar and put them in the black jellybean jar. Then, without **looking, I scoop five random jellybeans from** the black jellybean jar **and dump them in the red jellybean** jar. Are there the **same number of red jellybeans in the red jelly**bean jar as there **are** black jellybeans in the black jellybean jar?

Hints and Suggestions:

Consider the five random jellybeans that I transferred. **Suppose all five** of them were black. How would that affect the answer? What other possibilities are there?

But what about the pig?

Unlike these puzzles, real problems don't usually have neat solutions. You can solve a puzzle with a little thought; getting a pig out of your garden may take muscle as well. But the strategies that you use to solve puzzles may also help you with other problems.

Suppose your son won't clean his room, and your mother is coming to visit. What do you do? You could consider your goal. Do you want a clean room or a satisfied mother? If the goal is simply a clean room, the quickest solution might be cleaning it yourself. If the goal is a happy mother, maybe you could just keep mom out of the room so that she doesn't see the mess. Of course, if your actual goal is to teach your son responsibility, that's another problem altogether. Maybe you could use his allowance to pay for a cleaning service. The available options change when you evaluate your goal.

You might also consider your assumptions. Maybe your mother doesn't care if the house is neat. You could even think about breaking the problem into more manageable pieces. Today, ask your son to pick up his clothes. Tomorrow, work on getting him to make the bed. Drawing a picture of the room probably won't help much—though it might make you realize that the room has a door that you can close to hide the unsightly mess.

After you solve a problem, whether it's a dirty room, a pig in the garden, or a puzzle in a magazine, I suggest that you reflect on how you came to your solution. Think about the strategies you used, and maybe you'll discover one that will be useful for the next problem you encounter.

In the long run, being conscious of how you solve problems and thinking about effective strategies and approaches will help you become a better problem solver. And that's a useful thing. Because you can be sure of one thing, another problem is always just around the corner. If it's not one thing, it's another.

#3 HOMEWORK ASSIGNMENT

A physics professor ask… st… to do the impossible.

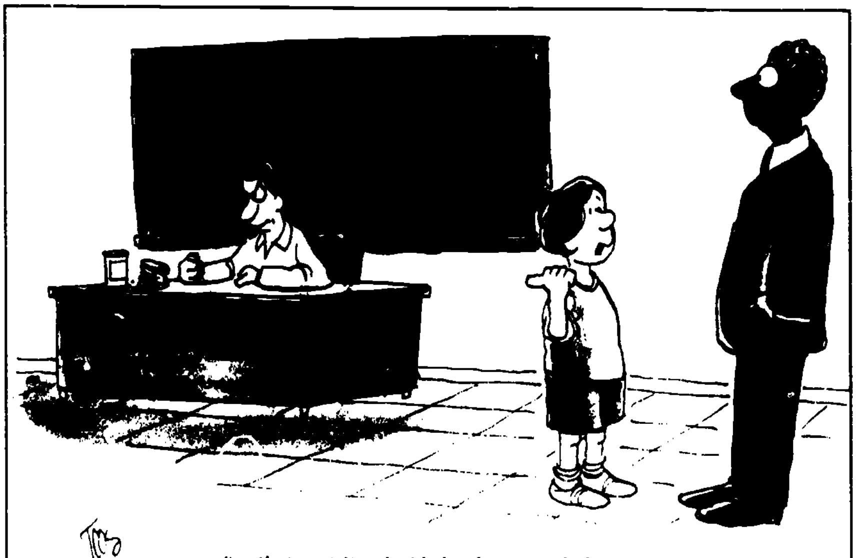
by Paul Doherty

FROM THE FIRST MINUTE OF THE FIRST DAY OF calculus physics, the students know that my class is going to be different. I walk into class with two one-gallon metal cans and place them on the lecture table in front of one hundred aspiring scientists, engineers, and doctors. Pointing at one of the cans, I say in a loud voice, "This can didn't do its homework." Then, as I turn around to write "Physics 151, Prof. Paul Doherty" on the blackboard, the can that I pointed to slowly, by itself, crumples into a wad of deformed steel. I turn around and admonish the class: "Let that be a lesson to you all."

This is my way of emphasizing the importance of working on the problems that I assign for homework. One of my main goals in this class is to teach my students to solve problems. They have been shown the tools for problem solving before in algebra and calculus class. Now they will spend a year learning to use these tools by solving ten word problems a week.

As a physics professor, teaching my students to solve problems is one of my most important jobs. After they take my class, I want them to be able to solve not only the problems they find in books, but also the problems posed by real life.

Let me show you a few samples of the problems I assigned to my class. I'll let you try to solve the problem, then I'll point out the important steps in getting the solution. I hope that in this short article you can learn a few of the lessons which I usually spread out over a semester.



"See that can? I've decided to be an English major."

I like to base my problems on real situations. The following problem, from the first homework I assigned to my class, is based on the strange fact that a person standing still on the equator is also traveling one thousand miles per hour. Because the numbers work out so well, this is one of the few problems in my entire physics class in which I use miles instead of kilometers.

Here's the problem:

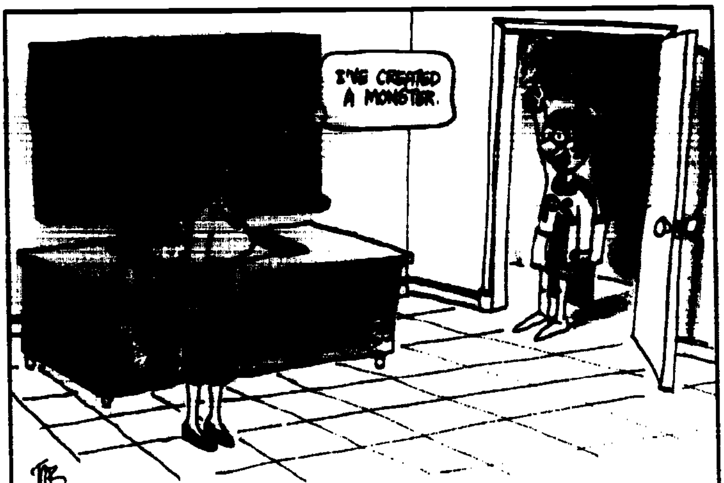
If you stand at the equator of the earth, the spin of the earth carries you around at 1000 miles per hour. How much distance do you travel in 24 hours?

To help students solve word problems, my first piece of advice is: read the problem out loud. If you can't solve the above problem by looking at it, try reading it aloud and see if that helps.

By reading aloud, you engage the part of your brain which looks for meaning in spoken language, in addition to the parts dedicated to visual perception. The important word in the previous sentence is "meaning." Before you can solve a problem, you must understand its words. Simply translating "1000 miles per hour" to "1000 miles in each hour for 24 hours" should help you find that you travel a distance of 24,000 miles, the circumference of the earth at the equator. (Of course, this problem ignores the movement of the earth around the sun.)

Difficulties arise when scientists take ordinary words and give them new meanings. For example, suppose the above problem asked for "your displacement in 24 hours," instead of "the distance you travel." The problem sounds the same in English, but its scientific meaning has changed completely. Your displacement is zero miles! To a scientist, the "distance" in this problem is the length of your whole trip, while the "displacement" is the vector, which is basically an arrow that connects your starting and ending points. Since you start and end at the same position, your displacement is zero. When I impose scientific meaning onto normal-sounding English words, it drives my students—and my editors—crazy.

Once students believe they understand the words of a problem, I then show them the next step in problem solving: making a sketch. If you ask me to solve a physics problem, I immediately reach for a piece of paper and make a sketch. After making my drawing, I label the parts so that the illustration contains all the information I have been given about the problem. I finish by writing down what I need to find.



"Stand back, it's PROBLEM SOLVING MAN!"

HERE IS A CLASSIC PROBLEM that's best solved with a drawing:

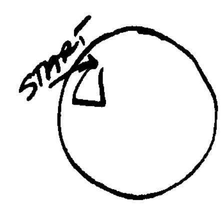
You are somewhere on earth. You walk one mile south and see a bear. You run one mile east, then one mile north, and are surprised to find yourself back at your starting place. What color was the bear?

The amazing thing is that this problem can be solved. Try it yourself. Make a drawing and see if it helps you figure out the answer. Your first sketch may end up like mine at right, which does not lead to an answer.

This figure was drawn with the unconscious assumption that the earth is flat, but of course we know that it isn't. Realizing this, I take out a globe and choose a few specific locations for my map. I redraw the figure for many places on the spherical earth—the coast of Antarctica, for example, or the middle of Canada. The drawings lead me to the solution.

Try it yourself before you read further.

When I drew the diagram in the middle of Canada, I noticed that the starting and ending positions were closer together than they were at the equator. Sensing the trend toward the correct answer led me to try places farther and farther north. I finally discovered that I ended up back at my starting point when I began at the North Pole. If I'm at the North Pole, the bear must be a polar bear and therefore it's white. We'll return to this problem later.



This is also an excellent example of a problem that students can't solve by simply plugging numbers into equations. I regularly spice up my homework assignments with problems of this type. To find the answer, they need to understand the problem and make a sketch—not just work out a mathematical formula.

If your first drawing doesn't help you solve the problem, take a tip from my friend Will Crowther, who suggests that you draw the drawing again, bigger. In the case of the polar bear problem above, a much bigger drawing would show the lines of your path converging slightly due to the curvature of the earth. If you notice the convergence, it might lead you toward the answer by encouraging you to try different places on the earth until you come to a place where the lines converge at the same point: the North Pole.

BY THE THIRD WEEK OF CLASS, many students are reading homework problems aloud to each other and drawing sketches. Generally, they are better problem solvers than they were the first week of school, and they can easily solve problems of the sort I gave them in their first assignment. The third homework assignment, however, is a very different matter.

At the start of the fourth week of class, when I walk into the lecture hall, the class buzzes with questions. One hundred students are unhappy with the homework assignment. Some of the best students have circles under their eyes from staying up late trying, unsuccessfully, to solve the problems. I collect the homework, and then ask for questions. Hands shoot up all over the classroom. One student demands that I explain how to solve the third problem. Before you read further, you might want to try to solve that problem yourself:

A bicycle racer maintains a constant speed of 20 km/hr on the first lap of a two lap race. How fast would she have to go on the second lap to average 50 km/hr for the entire race? Each lap is 20 km long.

My answer to the student's question is brief, but it brings a shocked gasp from the class: "You can't solve problem three."

I have done something to them that no other teacher has ever done, something that is both unfair and an important lesson. I have asked them to do the impossible.

Welcome to the real world. The problem seems reasonable, but no matter how fast the bicyclist pedals she cannot average 50 km/hr.

With a little effort, you can figure out why. Sketch a circular track. The first lap of 20 km at 20 km/hr takes exactly one hour. To average 50 km/hr for both laps, the entire race would have to take less than an hour. But the first lap has already taken an hour, so even at the speed of light, the fastest the bicyclist can average for the race is 40 km/hr. To average 50 km/hr, time would have to run backwards.

For those of you who like algebra, the problem looks like this:

$$\text{average speed} = \text{distance}/\text{time}$$

$$50 \text{ km/hr} = 40 \text{ km}/(\text{time for lap 1} + \text{time for lap 2})$$

$$50 = 40/(20/20 + t)$$

$$50 = 40/(1 + t)$$

$$50(1 + t) = 40$$

$$t = -1/5 \text{ hr}$$

(Negative time means she has to finish the second lap before she starts.)

In the class, I know what's coming next. The students demand to know why I would give them problems with no solutions. Many say they have spent hours struggling with the problems. My explanation is this: "Up to now, your teachers have spoon-fed you problems which were carefully designed to have one solution. However, when you leave this university for a job, the first problem you are given may have one solution, but it is just as likely to have no solutions or even an infinite number of solutions. As you search for a solution, you must continually think about how many solutions, if any, the problem you are facing might have. One possible answer is: none."

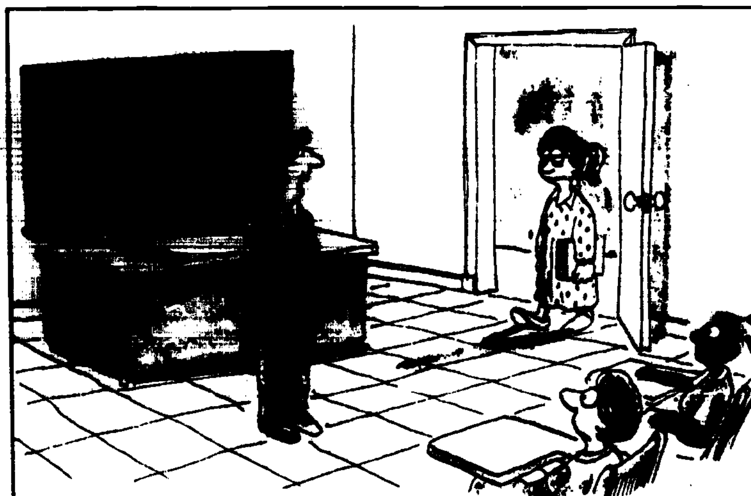
GREAT DISCOVERIES HAVE BEEN MADE by paying attention to all the solutions to a problem. Consider this one:

What is the square root of 4?

Don't forget that there are two answers to this problem: two and negative two.

Adding the second root seems like a trivial thing to do, yet it led physicist P.A.M. Dirac to predict an entirely new type of matter called antimatter. Dirac encountered negative roots when, in 1928, he solved the four coupled relativistic differential equations he had created for the electron. (And my students thought their homework problems were tough.) His solution produced positive and negative roots.

Two years later, Dirac realized that the negative root in his solution could be interpreted as a new kind of electron, one with a positive charge. The positively charged electron, subsequently named the positron, was discovered in cosmic rays in 1932 by C.D. Anderson. It is an example of antimatter: when a positron combines with an electron, both particles are annihilated. Dirac's prediction of the positron was an important part of the work for which he received the Nobel Prize in 1933.



"Nice try, Frances. But last night's problem did have an answer."

Some problems have more than two solutions. Did you realize that in the problem I posed earlier, the one with the bear, there are an infinite number of places on earth where you can take the described walk and end up back where you started? Can you find them? Here's a hint: think about starting near the South Pole.

Remember, the first solution you find might not be the best one. If you had found the South Pole solution first, you would be left scratching your head about the color of the bear, since there are no bears at the South Pole. One of the infinite number of South Pole solutions is drawn on page 34.

For years, I wondered about giving my students "Homework Assignment #3," the one with the insoluble problems. But then students like Cindy Heazlet began to come back to visit me after being in the workplace. She told me, "When you gave us those problems, I thought you were being unfair. But then I went to work at Lockheed. The first problem I was given was to design an attitude control system which involved solving six simultaneous equations. It was one of the hardest problems I'd ever been given, but building on your 'unfair problems,' I knew how to tackle it. Thanks."

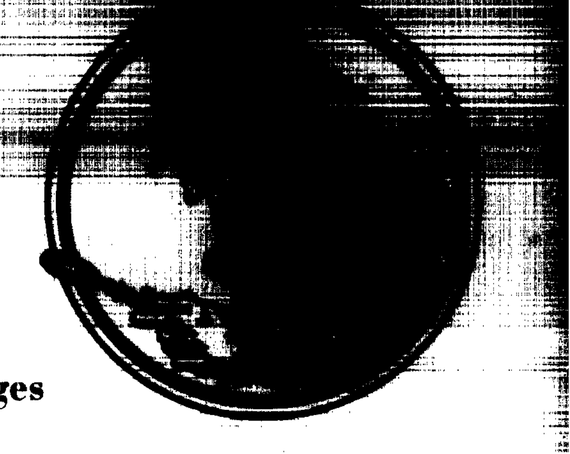
That made me feel good. But I never asked her what she thought about my starting the class with the collapsing can. ❑

*Note. To destroy a one-gallon metal can with a screw top, wash the can thoroughly, put a half-inch of water in the bottom, and bring the water to a boil. Let it boil for a minute. Take the water off the stove and screw the cap tightly onto the can. The can will be full of water vapor, but no air. As the water vapor inside the can condenses, the can will be crushed by external atmospheric pressure.

The Case of *The Smoking Brain*

Sherlock Holmes and the Art of Deduction

by Ellen Klages



It was a foggy night in London. A man lounged near the window of his sitting room, pensively smoking his pipe, the thick, aromatic smoke wreathing his gaunt features. A knock came at the door, and a florid stranger was ushered into the rooms at 221B Baker Street. Sherlock Holmes glanced at his visitor for a moment, then remarked to his friend Watson: "Beyond the obvious facts that he has at sometime done manual labor, that he takes snuff, that he is a Freemason, that he has been in China and that he has done a considerable amount of writing lately, I can deduce nothing else."

Watson, of course, was amazed.

Sherlock Holmes was a master of deductive reasoning. He carefully observed minute details about his visitor, linked them together in a logical manner, and stated his conclusions. His statements appeared astonishing because he left out the process and shared only the results. Or, as he said, "The train of thoughts ran so swiftly through my mind that I arrived at the conclusion without being conscious of intermediate steps. There were such steps, however."

Those steps—the chain of reasoning itself—can be as fascinating as the facts they reveal.

Although Holmes may be the most famous practitioner of the art of deduction, it did not originate with him, but with the ancient Greek philosopher, Aristotle, who set out the system for correct reasoning which we call *logic*. The primary structure in Aristotle's system was the *syllogism*—a series of statements that are related in such a way that if the first two are true, then the third one must also be true. The Romans called this form of reasoning *deduction*, because each statement "leads down" (*deducere*) from the previous one.

Holmes explained his reasoning process to the bewildered Watson. He was able to conclude that his visitor was a Freemason, he said, by observing that the man wore an arc and compass pin on his lapel. For Holmes this created the following syllogism:

My visitor is wearing an arc and compass pin.
An arc & compass pin may be worn only by a Freemason.
Therefore: My visitor must be a Freemason.

His conclusion is actually contained within the first two statements, or *premises* above, but it is not fully expressed. (You can show this by eliminating the repeated terms to reveal the conclusion: My visitor is ~~wearing an arc and compass pin. An arc and compass pin may be worn only by~~ a Freemason.)

Deductive reasoning is a tool that uncovers new relationships between known facts. Holmes didn't actually get any "new" information because the conclusion was implicit in the premises: he had seen his visitor's pin, and he already knew about the decorative habits of Freemasons. But when he linked those two facts together, what came from the deduction was a particular fact about that particular man that he didn't know before.

It seemed elementary to him, and perhaps to you. In a simple syllogism, the conclusion is fairly obvious. One, two, therefore three. But Holmes frequently found himself in situations so complex that neither the logical links between facts, nor the solution to the problem, were at all obvious. At least not until the entire chain of reasoning had been worked through.

It's difficult to illustrate how a truly tangled web of facts can be resolved by deduction without reprinting an entire Holmes story. Perhaps a brief example from another literary source will prove the point. Lewis Carroll, a logician as well as the author of *Alice in Wonderland*, often amused himself by formulating complex and baffling syllogisms as exercises for logic students to unravel. Here's one of the problems he devised:

There is no box of mine here that I dare open.
My writing box is made of rosewood.
All my boxes are painted, except what are here.
There is no box of mine that I dare not open, unless it is full of live scorpions.
All my rosewood boxes are unpainted.

Baffling indeed, eh, Watson? At first glance, these statements appear to be unrelated, and the conclusion anything but obvious. Carroll used examples like this as problems in symbolic logic, but it's also possible to solve them by "translating" them into more simple language, then rearranging the sentences in order to see the logical pattern more clearly:

My writing box is made of rosewood.
All my rosewood boxes are unpainted.
Only unpainted boxes are here.
If a box is here, I don't dare open it.
I don't dare open a box full of live scorpions.

Now the links between the premises begin to appear and, with a little thought, the hidden conclusion can be uncovered. (Try to figure it out using the trick of eliminating repeated terms. At the end of the article you can find out if your deduction agrees with Carroll's.)

Sherlock Holmes probably would have found Carroll's syllogisms amusing, but not enough of a challenge for his own keen intellect. His tastes ran to obscure and difficult puzzles, not mere exercises. He even berated Watson once for trivializing his deductive feats, saying: "Crime is common. Logic is rare. Therefore it is upon the logic rather than the crime that you should dwell. [Watson], you have degraded what should have been a course of lectures into a series of tales."

But Watson was right. Stories are more interesting than lectures. Holmes found the deductive process itself fascinating. But for most of us, just drawing conclusions—even strange ones—isn't that entertaining. It's way down the list as a spectator sport, unless the deductions are put into a context in which there is an interesting problem to be solved.

The reason we delight in Holmes' enjoyment of his own logical thinking is because he's involved in a mystery. The detective story, after all, is nothing more than a problem in deductive reasoning, camouflaged with interesting characters and a compelling story. We gladly follow the twists and turns of Holmes' reasoning process, page after page, as eager as he is to know the solution.

Sherlock Holmes was the quintessential Great Detective. He figured out the identities of criminals using powers of observation so keen that he noticed details that others missed, or failed to realize were important, like his visitor's Masonic pin. He noticed that the cuff of the man's jacket sleeve was shiny—as if he'd been leaning on a desk, writing.

He combined this keen eye with an encyclopedic knowledge of such esoteric subjects as tattooing methods (the delicate pink hue of the tattooed fish on the man's wrist, he told Watson, could only have been done in China), enabling him to form premises only he could know, and conclusions only he could deduce.

Because of his vast knowledge, Holmes always had an unfair advantage over Watson and the reader, who could only watch and marvel as the logic unfolded and the perpetrator was unmasked. The Holmes stories are full of brilliant deductions, but they are performances; you, the reader, are just an observer.

Then how are you to exercise your own deductive faculties and keep your wits sharp? Is Holmes a model here, too? Well, no. Holmes used a seven-percent solution of cocaine to keep his mind stimulated between cases. When chided by Watson for this unhealthy practice, he said, "Give me problems, give me work, give me the most abstruse cryptogram...and I am in my own proper atmosphere. I can dispense then with artificial stimulants. But I abhor the dull routine of existence. I crave for mental exultation."

He should have just bought a book of logic puzzles.

These "brain teasers" are more than mere exercises in logic—they are really mini-detective stories, in which the clues are revealed with the barest minimum of plot, setting, and character. Would-be sleuths and amateur logicians can enter into a rigorous process of deduction in order to solve mysteries like whether the plumber was wearing a blue shirt, or the nurse was sitting next to Mrs. Peabody.

All the clues/premises are set out, and it is up to the solver to arrange and rearrange them to reveal the hidden conclusions. They are teasers, though, because the best of them appear, at least at first glance, to be impossible to solve. Like this one:

"We're not keeping you busy enough, are we?" asked the man in the brown tie.

Mr. Green, Mr. Brown, and Mr. Black were dressed in identical suit coats, but each wore a different colored tie. "That's curious," said Mr. Black. "The colors of our ties match our last names, but none of us is wearing a tie that matches his own name."

"We're not keeping you busy enough, are we?" asked the man in the brown tie.

What is the color of each man's tie?

Is there really enough information here to figure that out? There is if you proceed logically. As Holmes said, "When you have excluded the impossible, whatever remains, however improbable, must be the truth."

So what is impossible? It is impossible for Mr. Black to be wearing a black tie, because we know his tie does not match his name. Is it impossible for him to be wearing either a brown or a green tie? Yes! One of those possibilities *is* impossible. He can't be wearing a brown tie, because the man in the brown tie is talking to him. So if he can't wear black or brown, Mr. Black has to be wearing the green tie.

Okay, how about Mr. Brown? We know he isn't wearing a brown tie (matches his name) and we also know he isn't wearing a green tie (worn by Mr. Black). Therefore, Mr. Brown wears the black tie, which leaves the brown tie around the neck of Mr. Green.

That was pretty simple, as logic puzzles go, but the principles are the same whether there are three guys with three ties or five people, each with a different color shirt, kind of pet, and make of car. All you need to solve these puzzles is logical thinking, and a keen eye for the clues you've actually been given.

A statement in a logic puzzle is rather like verbal origami—it can be unfolded to reveal other, more hidden conclusions. In this example, the fact that Mr. Black's name does not match his tie is stated; the fact that the man in the brown tie asks Mr. Black a question *implies* that Mr. Black and the man in the brown tie are two different people.

My mother adored these puzzles. She likened deductive reasoning to untangling a ball of yarn. In the beginning it looks like a big mess, she said. But if you concentrate on unraveling one knot at a time, it's simple, and after a while you end up with one long, connected thread. Watson agrees with Mom:

"I could not help laughing at the ease with which [Holmes] explained his process of deduction. 'When I hear you give your reasons,' I remarked, 'the thing always appears to me to be so ridiculously simple that I could easily do it myself. Although at each successive instance of your reasoning, I am baffled until you explain your process.'"

Now that you too have joined the ranks of Holmes, Watson, and my mother, no longer baffled by the art of deduction, you can try your hand at the logic puzzles on pages 15 & 16.

As for me, well, deduction can't solve every problem. I just discovered that my writing box is full of live scorpions.

Clowns & Crooks: Two Logic Puzzles

Clowning Around

Logic puzzles are like miniature detective stories—entertainments in deductive reasoning. You are given a situation and a number of clues, and your task is to become the sleuth and figure out who did what, when. Here's an example:

FIVE FAMOUS CLOWNS agreed to say a few words at the Funology Council meeting. In the past five years, each of them had won the coveted Golden Bozo trophy once, and each for a different innovation in clowning. From the information provided, determine the stunt specialty (one is pratfalls) for which each clown (one is Flippo) is famous, and the year (1988 through 1992) that each won the Golden Bozo.

1. *Andy's pioneering rubber nose work was not honored in 1992.*
2. *The 1989 Golden Bozo went to Curly.*
3. *The tiny car expert, who was not Boffo, took the prize in 1991.*
4. *1988's award honored the juggler.*
5. *Doofus received the trophy for his work with water balloons.*

That's it?

That's it, but it's enough.

Your first step is to determine what information you know for sure from each clue (either stated or implied) and also to determine what is impossible. Unless you can keep dozens of facts straight in your head, you may find that a diagram will help you keep the clowns in order.

There are two kinds of solving diagrams—grids and tables. Each of them arranges the information in a different way, and may help you to see relationships between elements. Here's a grid and a table to help you keep the clowns from running amok in your head. (I do these puzzles in pencil, and usually make a copy of the grid before I start, just in case I'm not really as good as Holmes.)

The grid is actually a truth table. Each square can be filled in with either Yes or No. (Visually, it's much easier to use a solid dot ● for Yes and an X for No.) Within each five-by-five section, every row and column will only have one ●, because only one clown is associated with each stunt, only one clown won in each year, etc.

You know from the first clue that Andy is the clown who used a rubber nose. So you put a Yes ● at the intersection of Andy and rubber nose. This means that it is impossible for any of the other four clowns to have a rubber nose, so put Xs in the other four boxes in the rubber nose row. It also means that Andy did not do any other stunt, so put four more Xs in water balloon and the other boxes in the Andy column.

You also know from the first clue that Andy did not win the trophy in 1992, so put an X at the intersection of Andy and 1992 (and, since Andy and rubber nose are the same, another X at rubber nose/1992). This doesn't tell you which clown or stunt *did* win that year, though, so you can't put a ● in the 1992 row or column yet.

Work through the puzzle once, filling in only the things you know for sure. You'll probably come to a place where you have a few ●s and a lot of Xs, and you feel stuck. That's where the unfolding part comes in. Try combining clues and see what hidden impossibilities that reveals. You know from Clue #2 that a particular clown won in 1989, and from Clue #4 that a certain stunt won in 1988. Aha! The 1989 clown couldn't have done the 1988 stunt, could he? Go put more Xs in the grid.

After a couple of connections like that, you'll probably be able to deduce some conclusions visually: once you've put four Xs in a row or column, you can see that only one box remains empty and has to be a ●. The table shows you somewhat different patterns; as you fill in the years, clowns, and stunts you know for sure, the blank spaces in the table will give you information about what possible connections are left.

There is enough information in the clues to determine which year each clown won, and for which stunt. Just take it slowly, one bit of information at a time. Determine what's true or impossible and then go on to the next piece.

(Answers are on page 34.)

		Clown					Year				
		Andy	Boffo	Curly	Doofus	Flippo	1988	1989	1990	1991	1992
Specialty	Water Balloons										
	Tiny Cars										
	Juggling										
	Rubber Nose										
	Pratfalls										
Year	1988										
	1989										
	1990										
	1991										
	1992										

Clown	Specialty	Year

Who-Dun-It?

This second puzzle is much more challenging. Even if you solved the clown puzzle in your head or on a piece of scratch paper, you'll need both the grid and the table for this one. If you skipped over the parts about the grid, go back and reread them before you tackle "Who-Dun-It?"

IT WAS A BUSY SATURDAY MORNING at the Famous Fictional Detectives Agency. Five different crimes had been committed, and a different sleuth was assigned to each one. Find out who did what by establishing the order in which the five detectives (one was Hercule Poirot) caught the crooks (one was Vic Vicious), and the weapons used in each crime (one was a garrotte; a different weapon was used by each crook).

1. *Sleazy Sol did it with arsenic.*
2. *Tom Trouble was caught right after the crook with the Bowie knife, who was nabbed immediately after Sherlock Holmes got his man.*
3. *Rick the Stick was the third crook caught. Emily Netterfield was the first sleuth to catch a criminal.*
4. *Ellery Queen caught the man with the Colt 45.*
5. *The crook with the derringer was caught immediately before Willy the Weasel, who was nabbed right before Kinsey Millbone caught her perpetrator.*
6. *Willy the Weasel did not use a Bowie knife.*

	Holmes	Millhone	N'field	Poirot	Queen	Rick	Sol	Tom	Vic	Willy	Arsenic	Bowie Knife	Colt 45	Derringer	Garrotte
Order: First															
Second															
Third															
Fourth															
Fifth															
Weapon: Arsenic															
Bowie Knife															
Colt 45															
Derringer															
Garrotte															
Crook: Rick															
Sol															
Tom															
Vic															

Order	Sleuth	Crook	Weapon

The two keys to solving this very difficult puzzle are unraveling the implied truths from the clues, and remembering that the events happened in a certain order, which creates a different set of impossibilities for you to use in eliminating "suspects."

Let's look at Clue #2. Hmm. It doesn't tell you anything for sure, does it? There are no ●s to put in the grid. But it does tell you a whole lot about what's impossible, if you look carefully. You now know that Tom didn't use a Bowie knife (because he was caught after that crook), and that he wasn't caught by Sherlock Holmes (because that was before the Bowie knife guy, and Tom can't be both before and after the same crook.) You also know that Holmes didn't nab the Bowie knifer, using the same reasoning. Put Xs in all those boxes (Holmes/knife, etc.).

Okay, what else do you know from this clue? Reading it carefully, you know that three separate crooks were caught in this order:

Holmes's man
Crook with Bowie knife
Tom Trouble

You don't know who's who yet, but you do know, looking at the list, that it is impossible for Tom to be the first or second crook caught. (Because you know that two crooks were caught before him, the earliest position he could occupy would be third.) You don't know for sure when Tom was caught, but you know first and second are impossible, so you can put Xs in the boxes where Tom/First and Tom/Second intersect.

At this point, it will also help if you fill in the table with what you know. Your best bet is to fill in the first column immediately with first, second, etc., in order. This gives you the beginnings of a list and may make possible relationships a little clearer.

This should get you started on the right track to deduce the rest of the information from Clue #2, and to go on and use the same kind of reasoning with the rest of the clues. (Hint: Clue #5 is structured exactly like Clue #2.)

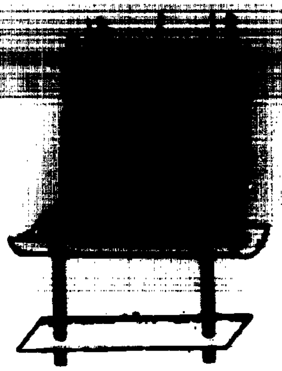
This puzzle is much, much harder than the clowns. You'll have to work to make deductions, but there is enough information to solve the puzzle. Really. If you get stuck, read each statement over again carefully, and look for hidden implications and contradictions. As you eliminate each impossibility, what remains has to be the truth.

If you get really, really stuck, and smoke begins to wisp out of your ears from your overworked brain, take two aspirins and check the answers on page 34. ❑

Fragments

Ruth Brown

In 1867, Margaret Knight invented [illegible] the universal problem of groceries spilling out all over the kitchen counter and making it possible for a single bag to hold twice as much as previous models.



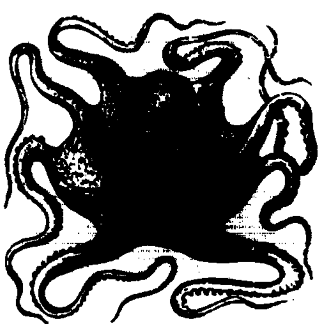
Pity the poor Victorian gentleman, who spent his days politely doffing his hat to the ladies. In 1896, James Boyle introduced the labor-saving device below. It was intended to spare the courteous wearer the inconvenience of putting down his parcels to tip his hat to a lady whenever his hands were full. When the man gently nodded his head, a weight inside the crown made the rim pop up. Boyle noted that his self-tipping hat might also be a valuable commercial device. When the hat bobbed up, it could reveal a printed advertisement hidden under the rim.

Long ago, the natives of Brazil found a way to deal with the discomforts of walking barefoot through the rainforest. They would stand in the liquid sap of the rubber tree and then let their feet dry in the sun. The result was a tough, flexible foot covering that protected their feet and gave them some added traction. When their rubber soles wore off, they simply re-soled with fresh sap.

When archeologists excavating the ancient city of Herculaneum uncovered a treasure trove of documents in 1753, salvage workers were delighted. They took out their knives, slashed off the outer coverings of the scrolls and hand-flattened what was left to see what was inside. This indelicate handling of the ancient texts made a Franciscan monk, Father Antonio Piaggio, cringe. Determined to find a way to save the charred, stuck-together scrolls, Piaggio devised a simple machine that gently opened the papyrus, pulling the layers apart and attaching them to a lining as they unrolled. The first papyrus that emerged from Piaggio's machine was the famous classical treatise *On Music*, by the philosopher Philodemus, in whose villa it had been found.

In 1762, a hungry gambler named John Montagu needed a way to eat his meals without leaving the gaming tables. He solved his problem by slapping some cold meat between two slices of bread, thereby inventing the famous food that was subsequently named for him. (His official title, of course, was the fourth Earl of Sandwich.)

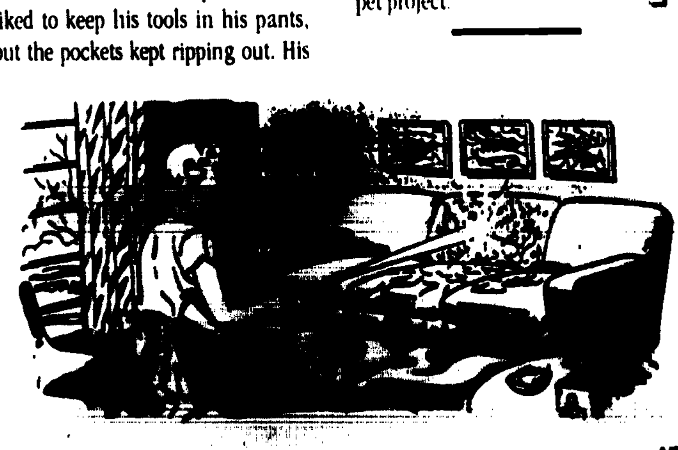
You might not think of an octopus as being very bright, but the lowly cephalopod is actually a pretty good problem solver. Two researchers in Naples taught a group of octopuses to attack colored balls: some learned to attack white balls; others learned to attack red balls. When untrained octopuses were allowed to watch just four demonstrations from an adjacent tank, not only did they learn to perform as well as the original group, they often did much better than the trained animals, working faster and making fewer mistakes.



Ohio dentist William Semple thought that people would have healthier mouths if they exercised their jaws every once in a while. In 1869, he invented chewing gum, convinced that it would solve the oral-health problems of America.

Back in the 1890s, a gold miner named Alkali Ike had a problem. He liked to keep his tools in his pants, but the pockets kept ripping out. His tailor—half in earnest and half in jest—took Ike's pants to the local [illegible] in the corners to reinforce the pockets. It worked so well that clothes manufacturer Levi Strauss began using metal rivets to secure the pockets on his newfangled denim jeans, and they're still used to keep pockets stuck on today.

In 1955, Frances Gabe (a pseudonym: her family was embarrassed by her work) tackled one of everyone's biggest problems: she invented the self-cleaning house. Gabe's prototype home, built in Newberg, Oregon, showcased more than sixty labor-saving devices of Gabe's own invention. At the flip of a switch, a trap door opened and the living room fireplace emptied itself of ashes. In the bathroom, a biodegradable seat liner was flushed away with each use of the toilet. At the touch of a button, water jets in every room soaked down everything in sight. (All the furniture, book covers, stereo equipment, pictures, etc. were waterproof.) Fans blew the house dry. Clothes hanging in closets were similarly bathed, as were dirty dishes stacked in the cupboards. For thirty years, Gabe worked on perfecting her drip-dry house, patenting each device as she went along, but she never found anyone willing to invest in her pet project. ❑



For most people, finding a problem means finding trouble. For scientists, finding a problem is the beginning of understanding

A Dialogue of Questions

by Adam Frank

For most people, finding a problem means trouble. For scientists, finding a problem is the beginning of understanding. The trick is finding the right problem. Learning to be a good scientist means learning to find the special problems that go along with important questions, the questions that need to be asked, the questions that can be answered. The rest, as a wizened old theorist once told me, is technique—all vacuum tubes and algebra.

How do scientists create problems? The answer, as we will see by looking at a few examples, is both mundane and profound.

[illegible]k at a Time: [illegible]o the Big Picture

S[illegible] the table of contents of any scientific jou[illegible] you will probably surmise that scien[illegible] great deal of time working on tiny [illegible]. The papers in most journals appear to focus on the arcane and even trivial details of obscure matters. The narrow focus of these questions, however, belies their importance. By choosing small problems individually, scientists collectively work out the broad patterns of the most all-encompassing theories.

When a scientist chooses a research interest, the first thing that happens is that he or she learns "the Story." The Story is basically the consensus of opinion in the community of researchers in that field. It's the present state of those scientists' attempts to create an all-encompassing theory for their discipline.

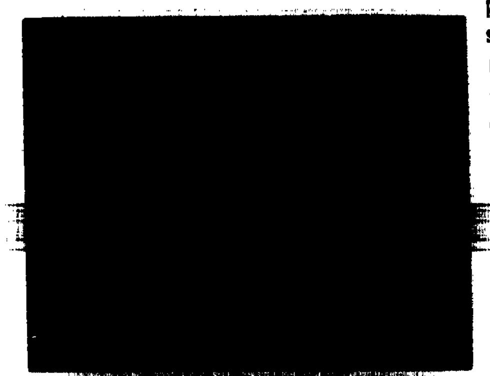
A scientist learns the Story by talking to people already involved in an area and by reading what are considered the seminal papers in the professional literature. The Story provides an overview of what the community thinks it knows, what it thinks is important, and what problems it thinks need to be solved.

Along with the Story, each discipline has its Problems-with-a-capital-P—one or two big questions that are like the Holy Grail for that particular community. In biochemistry, for example, finding the structure of life's building blocks used to be the big Problem—until James Watson and Francis Crick unraveled the mystery of DNA. In modern high-energy physics, finding a subatomic particle called the top quark currently constitutes the big Problem. The existence of this elusive (and perhaps imaginary) particle would confirm some of physicists' most crucial theories about the structure of matter.

Problems like these are so big and so involved that it usually takes an army of scientists working for years to find the answers. Over the years, a lot of people add small pieces to the puzzle. The solution to the Problem builds on the work of scientists who have gone before.

Science, by its nature, operates by consensus and usually moves slowly. Most scientists create smaller problems within the community's framework, where the edges of the big Problem are being tested and chipped away.

One day, a few years back, when I was an astrophysics graduate student studying in the Netherlands, my thesis advisor took me to a smoky old bar in the town of Gouda. There he introduced me to the wonders of Dutch beer and gave me my first shot at a medium-sized problem in astrophysics. We were studying planetary nebulae—big clouds of gases that surround dying stars. These gas clouds are blown off the stars in powerful stellar winds—at least, that was the Story.



The Problem that went with this particular Story was figuring out how and why these winds are blown off the star. My advisor's approach was to use the shapes of planetary nebulae as a key to understanding their history and the history of the central star.

According to the Story, the stellar winds that generate planetary nebulae should stream out into empty space. If that were true, then the outer edges of these planetary nebulae would look fuzzy as the gas expanded into a vacuum. My advisor had, however, noticed a curious pattern. Many planetary nebulae have sharp, not fuzzy, edges. My advisor thought this was an important pattern. He thought that the origin of the sharp edges of planetary nebulae might be a question worth asking. Since I was building a computer program to simulate the stellar winds, he also knew it was a question we could ask.

After experimenting with my computer program, I found I could reproduce the sharp edges found in planetary nebulae. Instead of letting the stellar wind expand into empty space, I let it expand into another wind, one that the star had blown off in an earlier phase of its evolution. Where the two winds collided, my program produced that distinctive sharp edge.

"Everything of importance has already been seen by somebody who didn't notice it." — Alfred North Whitehead

In the end, we found that we could match the patterns seen in real planetary nebulae quite well, and at the same time perform a kind of stellar wind paleontology. By seeing the sharp edges in planetary nebulae as the fossil imprints of old stellar winds, we could tell something about the history of the wind and of the star.

This observation didn't fundamentally change the way astronomers understood stellar evolution or planetary nebulae. It did, however, give me great pleasure. In a maze of data, we had found a small corner of order. When we asked the right question and looked the right way, one small pattern emerged. Out of the pattern, the right question, and the tools we had just built (the computer program), we could build a small tale to add to the big Story.

...ing for the Unexpected

...s led to the problem of sharp- ...planetary nebulae by the benign ... hand of my thesis advisor. ...ms are not always so easy to ...ometimes, crucial problems emerge from the worst clouds of frustration, appearing when things just don't go the way you expect them to. In these cases, the willingness of an individual researcher to turn away from expectations and confront confusion may allow a new and important problem to be defined and then solved.

Lord Kelvin (1824-1907)

In 1966, Arno Penzias and Robert Wilson, two Bell Laboratory researchers, had a problem. They had designed and constructed a big, horn-shaped antenna to pick up microwave radiation from communications satellites. But along with the microwaves from satellites, the antenna picked up an annoying little hiss that the researchers couldn't fix. No matter where they pointed the antenna, they found the hiss. It seemed to fill the sky with a perfectly uniform background of noise.

Since nothing in the sky could be that uniform, Penzias and Wilson reasoned that the hiss must be coming from the electronics in the antenna. They rebuilt the circuitry, but the hiss was still there. Then they thought that the hiss must be coming from the antenna itself. They checked and rechecked all the components in the antenna, and even went so far as to evict the pigeons who had nested there and scrub the bird droppings from the antenna's walls. For more than a year, they tried to get rid of the hiss, but to no avail. The noise would not go away.

Penzias and Wilson thought their problem was about electrical engineering, but when they asked electrical engineering questions they found only confusion and a mysterious hiss. But they didn't give up. Instead, they stopped asking what was going on with their antenna and started asking what was going on out in the universe. What could create a steady hiss that appeared to be coming from everywhere at once?

When they finally changed the question, they found the answer. By digging around, they found a paper published twenty years earlier that had predicted a steady hiss of microwave background radiation. The paper was known to only a small group of astronomers. By finding this paper and talking with these astronomers, Penzias and Wilson realized that the noise in the antenna was real. It was literally the echo of the moment of creation, fossilized radiation from the Big Bang, the primordial fireball that launched the universe.

Turning away from what you think is your goal is difficult. The expectations that scientists bring to their research are so powerful that data that don't fit are often simply ignored. Mathe-matician and philosopher of science Alfred North Whitehead once said, "Everything of importance has already been seen by somebody who didn't notice it." Other researchers at Bell Labs had known about the hiss that plagued Penzias and Wilson, but they thought it was of no importance.

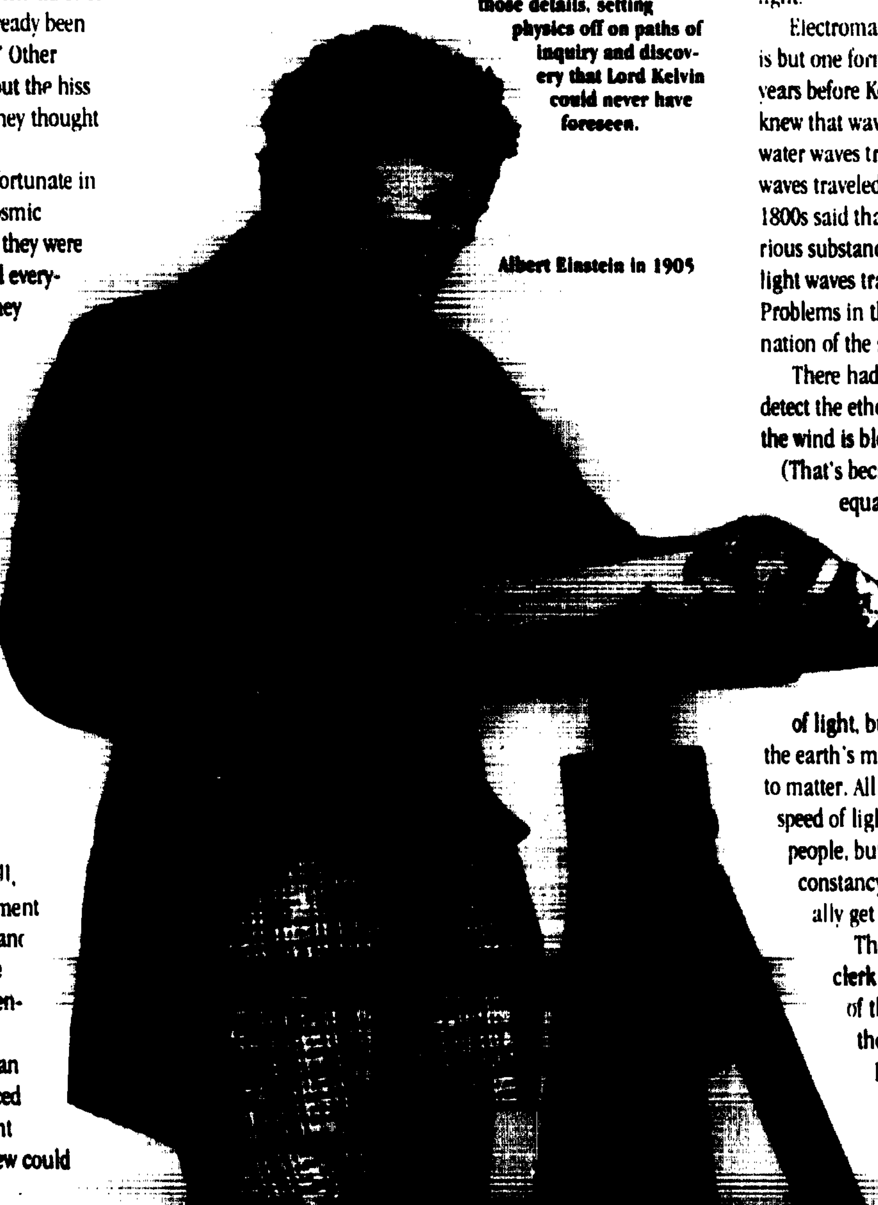
Penzias and Wilson were certainly fortunate in their discovery of what is now called Cosmic Microwave Background Radiation. But they were not lucky; they were creative. They tried everything to make their problem fit what they thought was happening. When that failed, they turned away from the door they had been trying to open for over a year—and found a different door.

They came to their problem, their real problem, through the back door. By turning away from their expectations, Penzias and Wilson turned their frustration into a Nobel Prize. In the process, they also launched the modern science and Story of cosmology.

C... a ...oblem; Asking ...r Question

S... a new and important ...ated by sheer force of will, ...serendipity. When the moment is ripe, a particular mix of arrogance and vision will enable someone to turn the Story on its head and precipitate a scientific revolution.

In the late 1800s, the great Victorian scientist Lord Kelvin proudly announced that physics was over. All the important problems had been solved. Nothing new could be expected. All that remained was getting more accurate measurements of a few numbers and cleaning up one or two small, unresolved details. One of those little details concerned the speed of light.



At the end of the nineteenth century, Victorian scientist Lord Kelvin announced that, except for some minor details such as the speed of light, all the questions of physics had been answered. At the beginning of the twentieth century, Albert Einstein began asking new questions about those details, setting physics off on paths of inquiry and discovery that Lord Kelvin could never have foreseen.

Albert Einstein in 1905

Electromagnetic waves (of which visible light is but one form) had been discovered about twenty years before Kelvin's pronouncement. Everyone knew that waves had to travel through something: water waves traveled through water and sound waves traveled through air. So the Story in the late 1800s said that all space was filled with a mysterious substance called "ether," through which light waves traveled. At the time, one of the big Problems in the Story of physics was the determination of the speed of light through the ether.

There had been a fair amount of effort to detect the ether. Sound waves travel faster when the wind is blowing than when the air is still. (That's because the speed of the sound wave equals the speed of sound plus the speed of the wind.) Scientists reasoned that light traveling through the ether would act the same way. People tried to use the earth's motion through the ether to measure changes in the speed of light, but, much to everyone's amazement, the earth's motion through the ether didn't seem to matter. All the experiments showed that the speed of light was constant. This bothered some people, but most thought that the apparent constancy of the speed of light would eventually get worked into the Story.

Then came Einstein. The young patent clerk from Bern didn't solve the problem of the ether. He didn't explain why the speed of light was constant, either. In fact, he ignored both questions. He played a kind of trick on physics by deciding there was a better question.

"What would happen," he asked, "if the speed of light were constant? What would the world be like then?"

To Einstein, the constancy of the speed of light wasn't a problem. It was an assumption. He used that assumption for building a new set of questions, a whole new problem. Einstein told people to forget about the ether and just make light a special kind of wave that needs no medium through which to travel. That was, and still is, a weird idea, but so what? Just because something is weird doesn't mean it can't work.

From the constancy of the speed of light, Einstein built the Theory of Relativity. That Einstein was willing to ask new questions showed his arrogance. The fact that they were the right questions shows his genius.

...Love the Questions

T... ...al kind of courage in Einstein's auda... what is worthy in his story did not depe... ...is special talents. By reinventing the world ...d his own questions, Einstein played out ... human drama, one that every child must star in. The world is a mess—a mess of sounds, colors, shapes, tastes, and touches. We feel compassion for newborn infants because they are thrown into a world that must be astonishing to their senses, a world that is buzzing with the unfamiliar and the unexpected. Somehow, in growing up, each of us learns to transform the buzz into something familiar, something that has sense and structure.

That is no small task. In our maturity, we tend to forget that the world and its buzz was ever so astonishing. But science cannot forget. Each time science tries to tell one of its Stories it must make the world unfamiliar again. Then the unexpected can stand forward. Science invents order through the willingness to recognize and question the astonishing chaos that lies at the heart of the world. ❑

The Problem Solvers

How do you learn about problem solving? One way is to ask people who are good at it.

In studying experts in various fields, some psychologists have found that people who are good at solving problems in one area are more likely to be good at solving problems in general. Expert problem solvers seem to be better than average folks at solving problems outside their area of expertise, simply because the experts know how to approach problems. They are less likely to get bogged down in details, more likely to review their progress—especially if they do get bogged down—and more likely to redirect their efforts to meet their goals.

In the following interviews, an auto mechanic, a physician, an exhibit builder, and an artist discuss their approaches to solving problems.

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Larry Gjerstad
Auto Mechanic

interviewed by Robert Pincus

When you buy a 1959 Studebaker you have to make a fundamental choice: you can become a good mechanic, or you can find a good mechanic. I found Larry.

Larry and his brothers know how to fix absolutely any car on the road. Judging by the photos on the walls, the shop's patron saint is a 1959 De Soto Firelite Sportsman, but the mechanics are as likely to be working on a new Lexus as an old MG.

Robert Pincus: Larry, you must see lots of different kinds of car trouble. What is the strangest problem you've ever seen in a car?

Larry Gjerstad: There've been so many. It's hard to remember them all.

Give me one of the greatest hits, then.

Well, we had a woman come in with a '63 Dodge. The blower motor for the heater would go, but it wouldn't blow out any heat. We got up into the duct work of the heater and there was all this straw and paper and whatnot blocking the way. It turned out that mice had built nests in there.

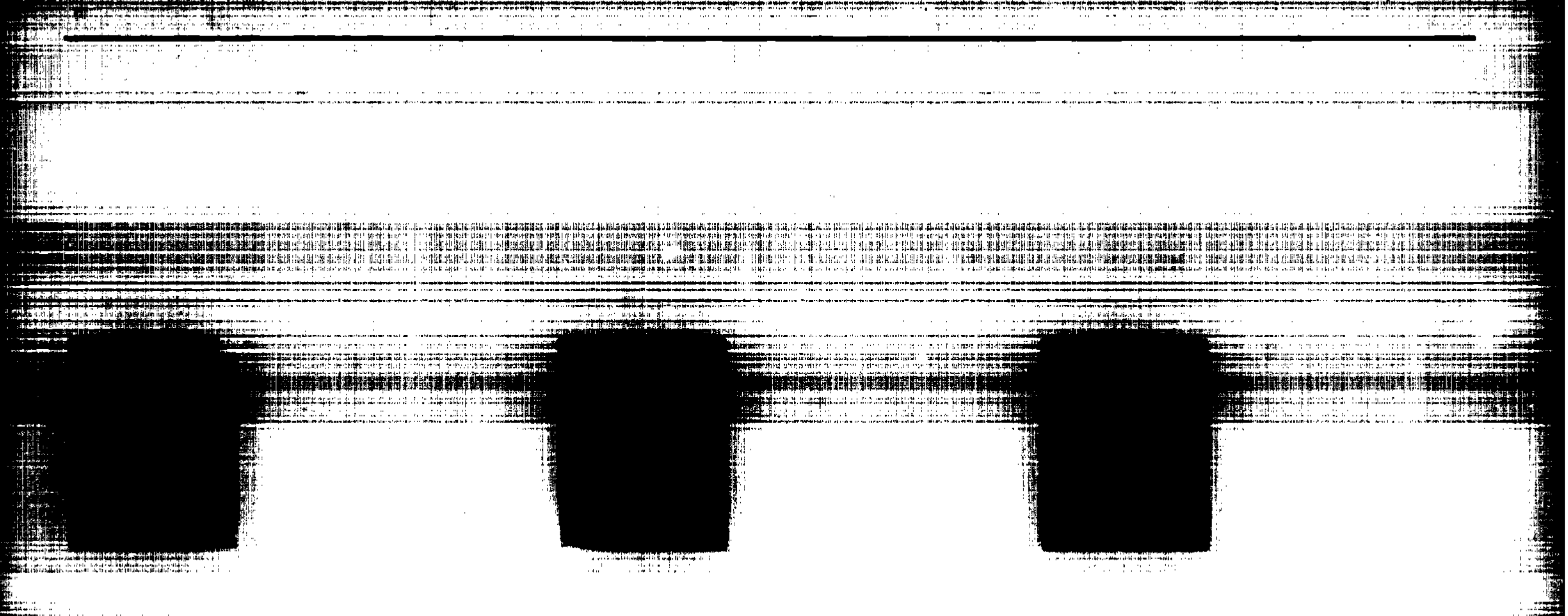
What made you look in the ducts?

Well, it was raining down little bits and shreds of this material, and pretty soon you had to dig deeper. There was a restriction in there. Obviously the car had been parked in a garage or a barn and these little mice made their nest in there.

How do you know where to begin looking when someone brings you a car that isn't working?

Peoples' description of what's wrong with the car usually points you in the right direction. If it doesn't run right, well, you're going to look at

MECHANIC, CONTINUED ON PAGE 24



Margarita Loinaz M.D.

interviewed by Pat Murphy

Margarita Loinaz is a doctor at San Francisco's Tom Wadell clinic for homeless and low-income people. She works in both the drop-in clinic, where people come with immediate problems, and in the primary care clinic, where she sees patients on an ongoing basis. She also visits a number of homeless shelters providing backup for nurse practitioners, and provides medical service at San Francisco's Day Laborers' program. Her patients include people from many ethnic backgrounds and she sees a variety of medical problems.

Pat Murphy: Suppose a patient comes to you with a complaint—like a skin rash or a headache. How do you go about figuring out what's wrong?

Margarita Loinaz: Before I can answer that, maybe I could try and give you a sense of what goes into making a doctor. Because the minute I start getting information from the patient, I'm tacking it on to this whole other fund of knowledge.

You start by studying basic sciences—chemistry, biochemistry, biology. Then you move on to anatomy and physiology; you start by describing the norm—how does a healthy body work? From that, you move on to pathology and the various diseases. What are the symptoms? How does the person feel? What's the epidemiological setting?

The epidemiological setting? What does that mean?

Epidemiology relates to the study of diseases or "epidemics" in particular populations. What ethnic groups have what kinds of diseases; in what parts of

DOCTOR, CONTINUED ON PAGE 26

Dave Fleming Exhibit Builder

interviewed by David Barker

Dave Fleming is an exhibit builder, designer, and ace troubleshooter at the Exploratorium in San Francisco. A shop fixture, "Uncle Dave" has repaired everything from Volkswagen generators to cosmic ray-detecting cloud chambers.

David Barker: You've got quite a reputation around here as a fix-it man. So what's the secret of your success? How do you do it?

Dave Fleming: Sometimes people will ask, "How are you gonna go about fixing this thing?" "Well," I say "I'm gonna take it apart, and then I'm gonna see what's wrong, and then I'm gonna fix what's wrong, and then I'm gonna put it back together."

That sounds simple enough. But how do you see what's wrong?

The process of elimination is always the first route. A typical example comes to mind: you're driving along the road and you hear "pow! siss siss siss siss siss...." You're not out of gas; you're not going to open the hood and start fiddling around with the carburetor. You look and see if a tire is blown. Solving any problem involves some similar process. A problem leaves clues—in this case, an audio clue.

Like a doctor, you have to be alert for symptoms. I remember one time my guitar amplifier was making this horrible buzzing sound, and a friend identified the problem by tapping on various capacitors and resistors with a pencil until one made a dramatic noise. That seemed an odd way to find the problem. I would have expected him to analyze it with a voltmeter, something more technically diagnostic. Do you

EXHIBIT BUILDER, CONTINUED ON PAGE 28

Ned Kahn Artist

interviewed by David Barker

Ned Kahn is an artist and exhibit builder at the Exploratorium. His fascinating and engaging exhibits operate somewhere in the realm between art and science, investigating such phenomena as meteorological and geological processes in an interactive and aesthetically beautiful way. His latest exhibit is a machine that blows giant, six-foot-wide smoke rings that float sixty feet into the air.

David Barker: Your situation appears quite different from someone who primarily fixes things and makes them work. You don't have a specific problem to be solved. Instead you seem to be looking for problems, like someone looking for an itch so they can scratch it.

Ned Kahn: Problem isn't exactly the right word. I try to let nature express itself, to create a system where nature has a certain degree of freedom to reveal itself and its ability to surprise. I think that's different from what a lot of artists do.

So you try to get out of the way, to be transparent and let the natural phenomena be the focus.

There are two aspects to the process. First, there are technical problems that you are trying to solve. For instance, right now I'm working on the drive mechanism for this vortex ring maker. I've tried four different mechanisms, but I can't keep the thing from making a clunking noise. Technical problems are an unpleasant itch.

On the other side are the conceptual problems, which are more of a joyous itch. Louis Kahn, the architect, once wrote that you can't build a building unless you are joyously engaged. Joy has

ARTIST, CONTINUED ON PAGE 30

Mechanic

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engine. If it makes funny clunking noises, then you check brakes, suspension.

Well, I can sometimes guess what part of my car is sick, but I don't have as much luck figuring out exactly what is wrong. How do you troubleshoot a car that won't start, for instance?

You have to know the basics about how something works. Once you know how it works, then you can go back and proceed through the whole system until you find the breakdown. OK, if the car won't start—I know the car needs fuel, I know it needs spark, and I know it needs air. Those three basic things. Usually it's missing one of those, and you can go back and start looking. If you don't have any spark—is the distributor turning? If it is, do you have power to the coil? If you have power to the coil, is it going through the coil?

> Once you understand how the system works you know what to look for when something goes wrong.

Would that work for any car?

Cars are pretty much the same for the most part. You've got a cooling system and an electrical system and a charging system and a brake system and various other systems. You see a lot of people with a lot of different cars coming in with the same types of problems.

What do you do with intermittent problems? A car that starts most of the time but dies at seemingly random times, for example?

You pretty much have to replicate the problem unless you've seen it before. If there's nothing presenting itself to you that's wrong, you can't in all honesty say that you've fixed the problem—no matter what parts you've thrown at the car.

If I can't replicate the problem, I try and get people to be observant and find out where and when the car does it, under what circumstances. Is the car hot, is it cold? Has it been running for five minutes, ten minutes? Does it do it going uphill, downhill, stop signs, hot weather, cold weather, rainy weather, dry weather? We need as much information as we can get, because the more information we have, the better decision we can make about what may be wrong with the car.

So if I bring in a car with brake trouble, for example, is there a standard procedure you go through to identify what's wrong? Do you start at the back of the car and move forwards, say, or start at the pedal and go towards the wheels?

No, not necessarily. It depends on the kinds of brake problems you're having. If you're hearing grinding noises, the first thing we'd do is take the wheels and brake drums off and look at the rotors. If you've got a low pedal, but you've got lots of fluid in the master cylinder, and everything is dry at all four wheels, then I know that it's probably an internal problem with the master cylinder. But maybe I'll look at the master cylinder and it's full, and I'll check at all four wheels and they're dry—then I know the fluid isn't escaping anywhere, so the problem is something internal that's not building up pressure. On the other hand, if I take the cap off the master cylinder and there's no fluid, I know the system is leaking somewhere, so I'll go down and check all the lines and hoses and wheels and whatnot. Usually I'll find where all the fluid is going.

It sounds like a lot of your knowledge comes from experience. You know what might be wrong with the car you're working on because you've seen it go wrong before.

That's exactly right.

Hmm. Well, what about changes in the way cars work? Cars are now being made with electronic widgets to do jobs that used to be done by mechanical widgets, or sometimes weren't done

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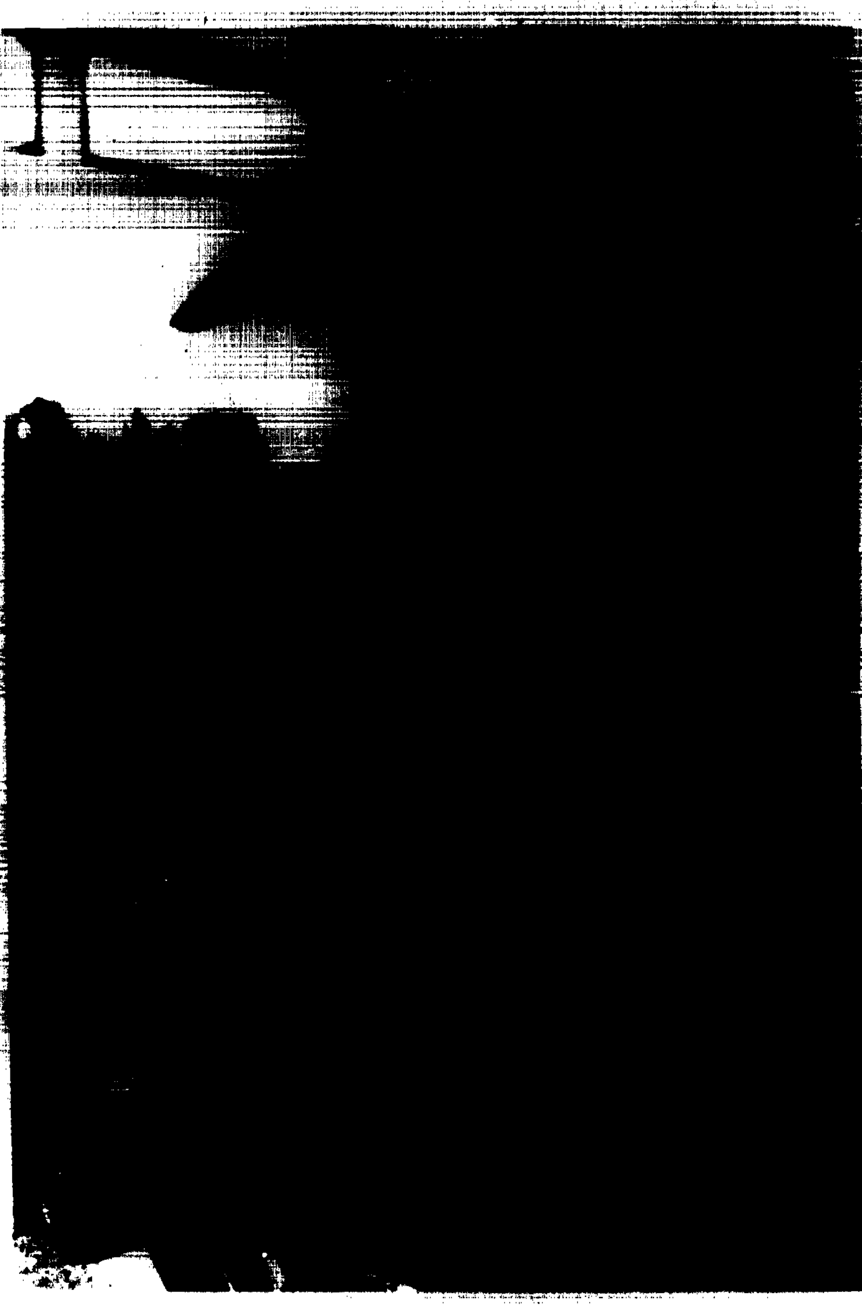
at all. Do the electronics change the way you fix cars?

The computers in cars make it easier in some ways and harder in others. They make it easier because they make the cars run better. Also, they are self-diagnostic. You hook up the big machine out in the shop to it, and our machine can tap into the car's computer which says "OK, there's something wrong in this system." Then you go to the book, and the book says, "If you get this code, check these things." Things do become more difficult to fix the more technology you put into them and the more sophisticated they become. But usually not that difficult, because once you understand how the system works you know what to look for when something goes wrong. And a lot of it is still the basics. Even in the brand new cars, engines work basically like they do in your Studebaker.



Is it more fun to fix the older cars, or is that my own wishful thinking?

For me, it's more fun to work on the older cars. The most interesting repairs are the ones where people have a driveability problem. The car stalls, the car does this, the car does that. You get to take the car and figure it out. It's like putting together a little puzzle. It's more of a challenge, more fun to figure out when something's going wrong. And I like cars that I don't have to hook up to a machine to figure out what's wrong.

What do you do when you can't figure out what's wrong with a car? What do you do when you get stuck?

You talk to people you know: mechanics from other shops, friends, people you've worked with before. You call a dealership and ask them if they have any more information, maybe a technical bulletin. Maybe the problem will ring a bell with somebody and they'll say, "Oh, yeah, I ran into that and this is what it is.

"And there are any number of toll-free hotlines that you can call. But we haven't had to resort to phone calls much. Everyone in this shop has a lot of knowledge. If somebody comes across a problem that they don't understand, they can ask someone else. Lots of times, the other guy will come over and say "There it is. Your problem is right there."

I imagine you've worked with a lot of different people over the years. What makes somebody a good car mechanic?

Well, I think some people have a natural aptitude or natural mechanical ability. Being logical helps. A lot of common sense. Having a good memory for things. Storing information that you run across so you can recall it when you see it again. And a lot of logic. ❑

Doctor

from page 23

the world are certain diseases more prevalent.

[illegible] travel. If you come back to the States with some disease you picked up in Nepal, you have to make sure that the doctors know where you've been. Otherwise they won't know what to look for.

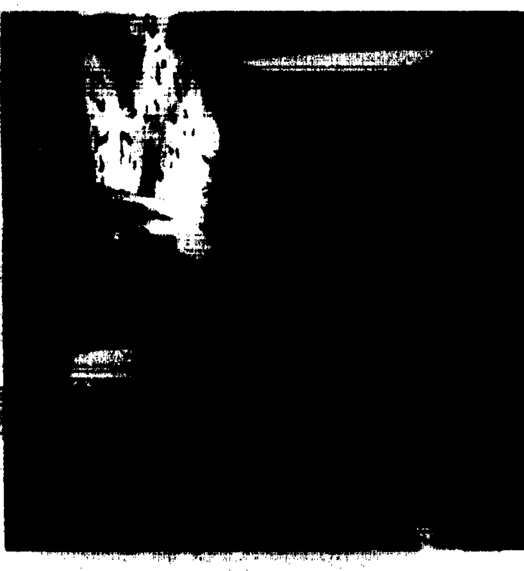
Yes. That's really important because the symptoms for some weird parasite from the Himalayas and the symptoms for giardia, which is common in the States, could be similar. If you're not looking for a weird one, you may not catch it for a long time.

Let's get back to what happens when someone first walks into your office with a medical problem. What do you do?

First you take a history. You find out what's the chief complaint. It may be a cough—that's so common. And you want to know: Is it a dry cough or a productive cough? How long has the patient had the cough? Is there fever? Weight loss? Any other things going on? Nausea, headache, so on.

Once you know the chief complaint, you start seeing what else is associated with it—this is the history of the present illness. Then you move on to past medical history. That's going to influence things too. If it's somebody who has asthma or who has risks for tuberculosis or cancer, the cough takes on a whole other dimension. And then you ask if they are taking any medicines—sometimes medicine can give you a cough. You ask about allergies to medicines.

Give the same set of information to three different doctors and they'll give you three different treatments.



You get this information and you associate it to your past experience and knowledge and you make a differential diagnosis. That sounds simple, but asking the right questions and doing a good assessment is a skill that develops with experience. That's why some old docs are just incredible. They hear a history and they know the problem's going to be this or this. Your clinical judgment develops over time. Sometimes, just by looking at a patient, you know when you can't afford to waste time and when maybe you can take your time.

It almost sounds like pattern recognition... like, you have the history, and you have your past experience, and you make associations, and then you see where this problem fits into what you've seen before.

That's exactly it. It is pattern recognition. And as you work and acquire more experience, the number of patterns you recognize and the subtleties of those patterns increase. Yeah! I guess you probably could pretty much reduce things to that. Even when you just get a kind of instinctive feel about somebody that's walking into the clinic and you look at them and you say, "OK, let's take care of this one first."

You've seen this before. You recognize it.

You get a feel for it. Exactly. You recognize it.

So you take the patient's history. Then what?

Then you move on to the physical exam. When you're training, you do a complete physical from one end to the other. But in the real world, when you're out there practicing, your exam is geared to the chief complaint. If you're dealing primarily with cough and shortness of breath, you're going to be concentrating mostly on the lung exam and maybe on the heart exam. Your exam is guided by what you think may be going on.

For example, if you have a young, healthy person with a cough, you're not necessarily going to worry about their heart. But an elderly person with a history of heart disease could develop a cough from heart failure, which causes fluid to build up in the lungs.

After you take the history and do your physical exam, you order the tests you want. You could get an electrocardiogram if you need to check the heart, or X-rays if you're worried about pneumonia or fluid in the lungs. And when you get the results back you make a decision. Sometimes—a lot of times—we're not a hundred percent sure.

That's interesting. Other problem solvers that we talked with mentioned the role of the mistake in the process. When you're working on a car, for instance, you try to fix it and maybe it still doesn't work. But in our society, we tend to think of doctors as people who aren't supposed to make mistakes.

Medicine is by no means an exact science. Give the same set of information to three different doctors and they'll give you three different treatments. If you're dealing with bronchitis, say, one doctor may let the person go away without antibiotics, another might give them this kind of antibiotic, and a third might say, "I would never give them that! I would use this." There's room for different approaches.

So basically, it's a judgment call.

Many times I'm very conscious that I'm making a [illegible] and I try and cover for the worst. When you know you're not certain, then you cover for the thing you think is going to kill the person. But you still may not have a definite diagnosis.

When you say a diagnosis you mean you know exactly...

It means you are certain. You know what is really going on. Is this definitely pneumonia or is this just a bronchitis, for example.

You get to the point where you think, "Well I'm pretty sure it's this," and then you decide how to treat it. When you're figuring out the treatment, what sorts of things do you take into account? Do you take into account age or ethnic background or living situation?

Absolutely. Let's take bronchitis. There's a viral bronchitis that you can't do anything about. You just treat the symptoms. But let's say the person is elderly, or a smoker, or they have asthma, or cardiac disease and heart failure. In those people, I'm going to be a lot more aggressive and err on the side of over-treating. Because if I'm wrong and it's not a virus, if it's a bad bacteria, they can develop much worse consequences if I miss it, so I would probably use antibiotics.

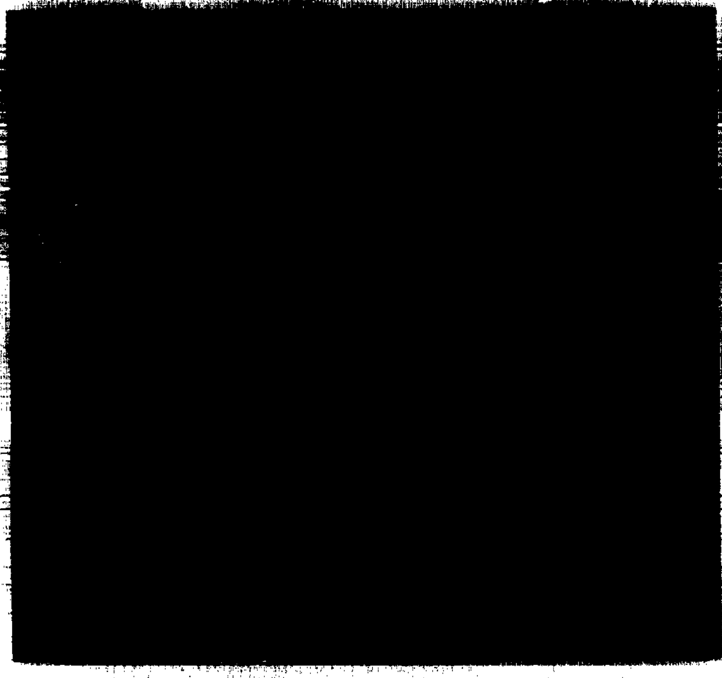
It's a very multi-dimensional approach to problem solving, where you are taking a lot of things into account. I think that's why the training takes a long time.

What other factors affect what treatment you might prescribe?

You have to make sure the person is going to comply with the treatment. If you have somebody who doesn't have a place to live and they have an infection in their leg and you tell them to lie down and put their leg up—it's ridiculous. So I ask all the time, "Do you have a place to live? Is my treatment going to be something you can follow?"

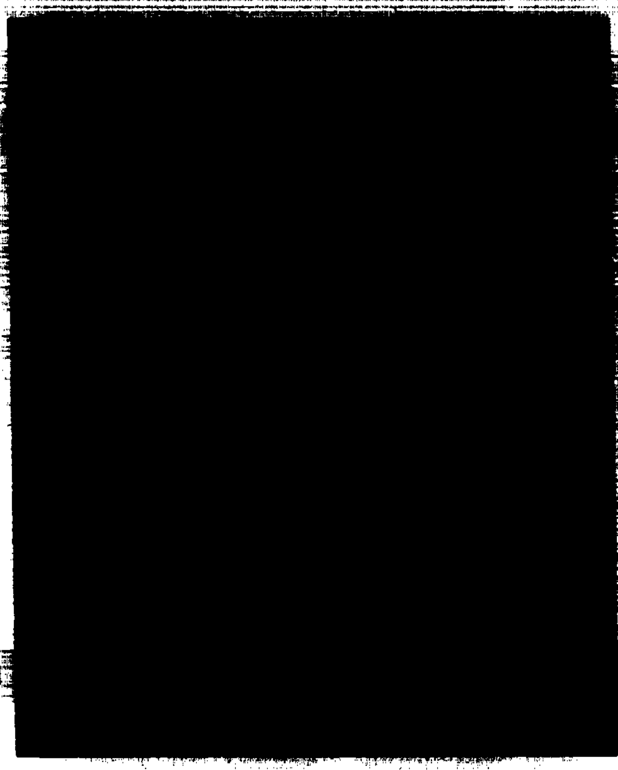
Or suppose you have a patient from Asia. Many people in those communities look at Western medicine as being really "strong." They feel that their herbs are much milder; our stuff is too concentrated. So if you tell them to take one pill twice a day they'll take it maybe once a day. Or once every other day. They're adjusting it to what they think is the proper concentration for them. So you have to make sure they understand how important it is for them to follow through with the treatment.

[illegible]o you ever get stumped? If you can't figure out the answer to a problem, what do you do?



Well, different things. You can just keep testing until you run out of tests that are reasonable to do. And sometimes you just watch. They always talk about the "tincture of time"—letting time sort things out. And it's true. Often, people improve without any treatment. It's also important to know your limits. You should know when to get other specialists involved in the case.

Obviously you've got a patient and you're dealing with a person. But at the same time, you're dealing with a problem and you can get intrigued by the problem. Is that something that you've observed—that you get intrigued by the problem?



And you forget about the person?

Maybe forgetting about the person is too strong, but it seems like you must be shifting back and forth between two viewpoints all the time.

It's true. Especially when you get somebody with an unusual problem. It's very exciting. I think a lot of us love that part of medicine that is like being a detective and figuring out the answer. I've caught myself at times searching in my head and reeling with ideas because it's an interesting situation that I've just read about or something. At the same time, you have to come back to your relationship to the person and support them and be compassionate and caring.

I think that the best doctors are the ones that are really intrigued. Physicians need to have a real curiosity. Because it's the curiosity that drives you to keep going, to keep looking when you don't have a ready answer. ❑

from page 23

sometimes just push things around to make the problem reveal itself?

In that case, your friend had the experience to know that the mechanical vibration of the amplifier's speaker could be picked up on a microphonic component, which means that the defective part was acting like a miniature microphone. If you didn't have a clue that that was what was going on, it's quite possible that you'd methodically approach it with an oscilloscope. A similar approach is to use a can of Freezit to make the components really cold. If a resistor heats up too much and opens or changes its resistance drastically, it'll cause static or some other effect. So you cool it down and all of a sudden the problem either comes in even stronger or goes away. It could work either way. There are similar techniques, such as banging on parts with a pencil. But again, it's a combination of common sense and experience.

You have to set up a situation so you're free to make mistakes.

So you change some part of the system to see if it affects the problem, for better or worse. You're trying to find "who dunnit" without looking for a motive. Do you look for things that are out of place or different?

You have the same sort of psychological approach as someone who tracks animals or people in the forest. You have a variety of clues to look for. A heavy-set man will leave deeper footprints. Someone running will put more weight on their toes. In the electronics situation, you might see a part that's blackened or bent. If there's something funny looking, out of the ordinary.

How do you employ modeling and prototyping?

Modeling gives you a reality check before you start to build some big, complicated thing. You can check it out on a small scale or in a simplified version. You can disassemble the problem into smaller segments and work on them before you are committed to putting it together as a whole.

What is the role of the mistake in the process?

Some people get quite frustrated if they think they've failed to fix something or have built something they feel doesn't work. That's a difficult psychological thing to deal with.

You have to set up a situation so you're free to make mistakes. Essentially, it goes back to modeling and prototyping. That's what they prevent. You are defining what parts of the problem you understand and what parts you're unclear on. But some of it is a matter of semantics: mistake is almost a derogatory term, you don't really want to call it that. More accurately, it's trial and error.

Or trial and error and trial and... "Eureka!"

It's like an iterative process of zeroing in on a number in a math problem. You just pick two numbers as possible solutions: whichever is closer to the answer, you continue in that direction. You keep changing "x" a certain amount, and if you over-shoot, you have to go back, and you eventually zero in on the answer. Practically, working with gadgets, you use this technique all the time.

For instance, if you wanted to find the cube root of 729, you could try cubing some numbers: 4 is too low, 18 is way too high, 8 is a little too low, 11 is a little too high, 9 works.

For an electronics problem, you might take a drawerful of resistors and start plugging them into a network, say to get a meter to read in the right range. You don't want to sit down and engineer the whole thing. Designing mechanical linkages can be approached the same way.

What motivates you to go to the trouble of fixing things rather than paying someone else to do it and save you the hassle?

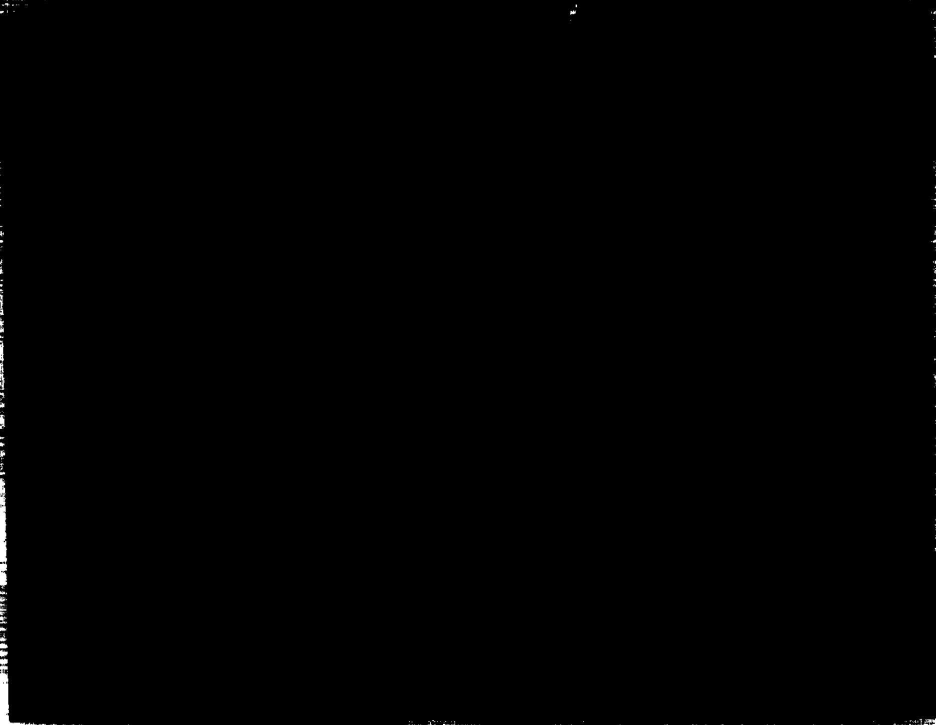
Sometimes you get a car part and you say, "Gee, I wish I didn't have to spend forty-five bucks to replace this thing." So you open it up just to see if there's any hope. Sometimes there's a little broken wire, a little dirt on the contacts, and you can go in there and clean it off. I'll usually try that first.

Money, economics, it's a great motivator. But it's also the challenge of trying to solve the problem and the satisfaction that brings.

The advent of the computer has forced a large segment of the population to become problem solvers: it's often a struggle at first to get a computer to do what you want it to do. You've been using computers for some time now: how do you feel about solving problems with computers?

You know, I heard an interesting study about how people learn to use computers. There were two different groups of people, and each group was given an identical computer problem—in this case, it was a game. They had to learn how to manipulate the game to achieve a particular goal.

The first group was given a specific set of instructions to give them a basic structure on how to solve the problem. The other group was told nothing; they had to just figure it out for themselves. The first group—the group with the basic set of rules—was able to accomplish the task [illegible]er, obviously because they were given the hint.



The second group, working it out for themselves, was eventually able to solve the problem as well.

Then the experimenters gave each group a second problem, but the program was changed so the initial set of rules no longer applied. It turned out that the people that got the hint the first time around couldn't solve the second problem as fast as the people who'd figured it out for themselves. The second group learned how to manipulate the computer to get it to do what they wanted, so they were able to solve the second problem faster.

A lot of kids learn that way, too, hunting and pecking around in seemingly chaotic fashion.

When you get frustrated, when there seems to be no hope of figuring out an answer, how do you get unstuck? Do you ever dream solutions?

Sometimes projects seem to drag on and come up against one block after another. These are best pigeonholed until solutions make themselves available—unless it's really important and you've got a deadline or a budget.

Not concentrating on a difficult problem is often a good way to let the solution turn up. Once I was repairing an old vacuum-tube-regulated power supply that had completely melted its wiring harness. It was a nice piece of equipment that I couldn't bring myself to throw out. Most of the melted wires could be retraced, but some were missing. I began drawing a schematic to understand how the different sections worked, but I couldn't see what was missing. The next morning, as I was just about to wake, the schematic I was pondering over so much on the previous day became the first thought in my semi-conscious state. A solution suddenly, effortlessly popped into mind. When I got to work, I walked straight over to my desk, grabbed an alligator clip and connected two ground busses together. The unit was completely functional. There was no applause.

That moment when frustration turns into insight, when the proverbial light bulb goes off, that must be the most attractive part of problem solving.

When things are not going well, the natural feeling is to kick the gadget or bang on it or something. At that moment, I try to stand back and say to myself, "Pay attention, Dave. You're probably about to learn something." ❑

Artist

from page 23

to be the underpinning of any great endeavor.

Your [illegible]
You seem more interested in the aesthetics of phenomena.

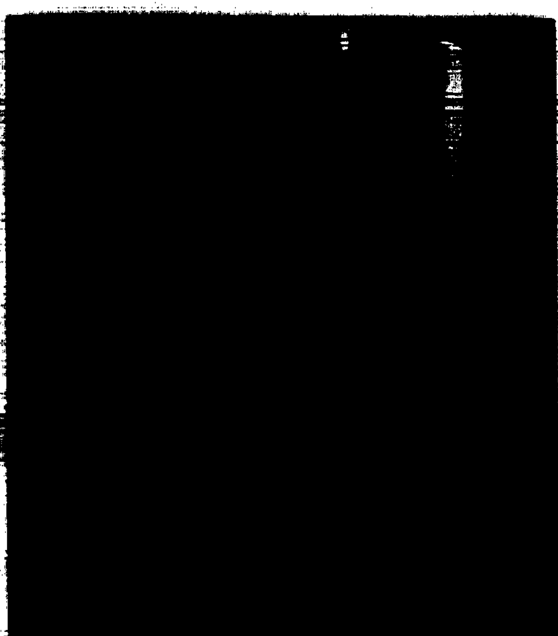
People often say that what they like about my exhibits is that they're so simple. The reason they're simple is that when I introduce the slightest bit of complexity it's always a complete failure.

Technically speaking, I've learned just enough so I can do what I want to do.

Joy has to be the underpinning of any great endeavor.

Most of the exhibits I've made are a lot of lucky discoveries. I'll discover one thing while looking for another thing, and not knowing what to do about it, I'll forget about it for a few years, and then go back to it.

Let's take your Turbulent Orb exhibit as an example. You've got a glass globe that's maybe two feet in diameter, filled with blue liquid. When you rotate the globe on its stand, the liquid forms turbulence bands not unlike those seen on the atmosphere of Jupiter or earth. When you built that exhibit, did you have a general conception of what you wanted to demonstrate?



Actually, it began with the glass. One of the other artists here found some big glass spheres for one of his projects, but he never used them. They're just beautiful objects. The sphere has a natural association with the planet and with weather, and I was thinking of making something that was evocative of the atmosphere.

So the object rather than the phenomenon got you started—what can I do with this nice thing?

Then it was just a matter of playing around with the components until I reached the point where what they did was interesting enough on enough levels. I was also stuck with the technical problem of what goop to use in there to make the flow visible. Some of the materials I tried settled out after a while and you had to stir it back in somehow. [illegible]ome were organic and those [illegible]

I remember you had some problems with stirring the material. Your final solution was quite elegant.

It came down to trying a million different things. In the end, the simplest solution was just rotating the whole sphere, rather than rotating the material in the sphere.

If I were trained in atmospheric physics I might not have thought of that. Because I would have been trying to make it a true physical model of the atmosphere, and the exhibit's not that. Rather than the earth spinning and driving the atmosphere, it's more like space is spinning.

But it shows the effect of the phenomenon wonderfully.

But it's really just a lucky coincidence.

When you're building your exhibits, how much time do you spend solving technical problems, as opposed to working on the central concept?

The real creative vision or insight is about one percent of it, but it's what gets the process rolling.

How do you deal with those inevitable moments of frustration, when you don't seem to be on the right track?

The main way I deal with frustration is by having a number of different projects going at once. When you get stuck on one thing you leave it and go on to something else. I have a very slow mind, and sometimes it literally takes years to figure some things out.

When you're in the middle of a thorny problem, do you have any strategies for getting unstuck?

I guess what I do is go ask Uncle Dave.

So you get some input from someone with a whole different approach? Someone with another perspective?

Without Dave and other people, I would probably figure it out myself, but it might take months. Talking to other people jogs me out of my train of thought.

Do you sketch out ideas, like on graph paper and so on—design an idea out of your head?

I'll get an idea for something and put it down on paper so I'll remember it. I'd say with ninety-five percent of those ideas, I'll come into the shop the next day and make a little prototype. Of those, ninety-five percent are immediate and complete [illegible] when the idea actually interfaces with [illegible] things grow out of just doing that.

For example, I was thinking of a variation on the Turbulent Orb. I was wondering what would happen if I had a spinning flexible disk inside of the glass sphere. It was something I hadn't tried. So I cut out a rubber ring and I bolted it onto a rod and I stuck it in the sphere and tried to spin it and it was a complete failure. It wadded up and flopped around in there and I plucked it out before anyone could see it.

But then I was sitting at my desk with this rubber ring on a shaft, twirling it in my fingers, and I noticed something interesting. At various speeds, it was forming interesting oscillation patterns.

So I clamped it into my drill, and spun it around, and it had all these other emergent properties at certain speeds. And then, in sort of a bizarre twist, I showed it to a couple of physicists, and they concluded that it was actually a good model for the jet stream. So it was something that had started in my mind, which was a complete failure, but by a completely unpredictable path ended up tying in to something larger.

A big part of this is the interaction with real materials. Rather than sitting at your drawing table with graph paper, it's much richer dealing with real materials; your senses come into play. When you're drawing something out in your mind, you're limited to what you know.

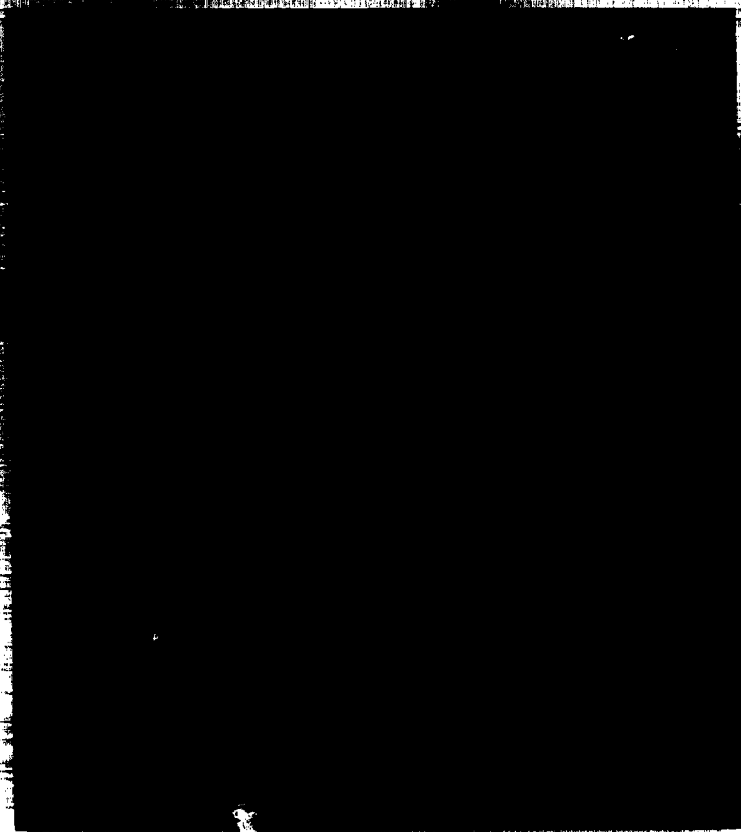
That's interesting. You're limited by your imagination, which is supposed to fling you off in all directions, but you're actually trapped by it. So, do you use a sort of ping-pong technique: work with materials on the physical level, then sort it out in your mind, then physical, then mental, and so on?

Yeah, that's pretty much it.

Do you consider your working situation to be akin to an experimental laboratory type of setup?

It is important to have a critical mass of stuff around to prototype with. I remember reading in a philosophy of science article about the principle of limited sloppiness—basically describing how a number of scientific advances have come about because the scientists were somewhat sloppy. If they were too sloppy, it would be a mess, complete chaos. But there's a middle ground where there's a chance [illegible]andom events being worked into the equation.

Do you feel a [illegible] working within the same general area in terms of the phenomenon you're trying to investigate, like an artist with a particular style?



There's a group of questions that I'm interested in at a certain time, and it's definitely followed a progression. I started out with bubble exhibits, and I became interested in watching the movement of currents in the soap film. That led to my interest in fluid motion, which led to an interest in chaotic systems, which led to weather, from which I became interested in other geophysical, geological processes. So it's a meandering course, and it branches, and sometimes you go back to earlier parts of the stream. But they are all somewhat connected.

When you're making exhibits, how do you know when you're done? When do you know if you have the right answer?

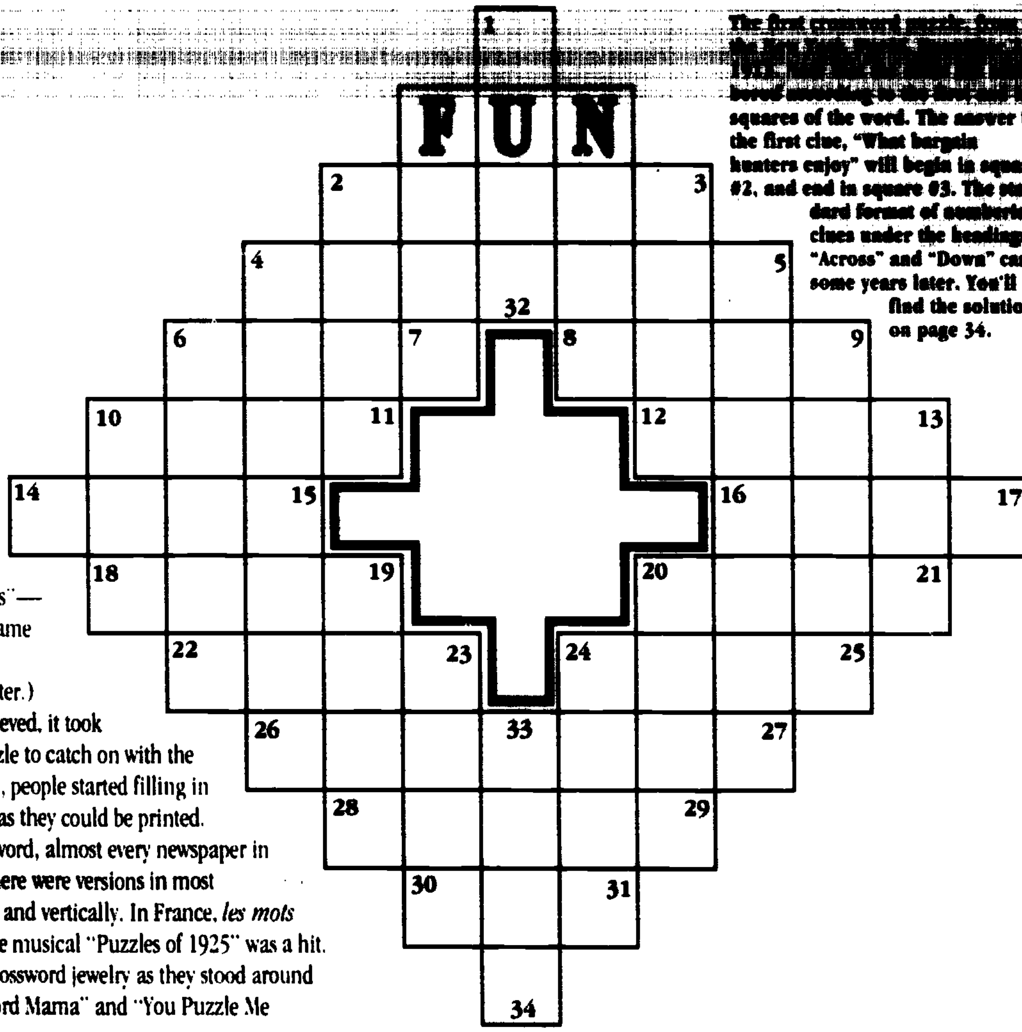
The process is perhaps more akin to painting: you look for an economy where you achieve the richest amount of experience with the simplest means. Sometimes, through the prototyping process, the exhibit starts getting more and more complicated as you get more ideas. So you start throwing things out, or separate the parts to use them for other exhibits.

And sometimes it goes the other way, where you're adding things and trying new approaches: "What would happen if I did this... or what if I tried that...?" Maybe each of those additions makes it a little bit better, but not that much. Then you do a third thing and suddenly it's a whole lot better. It has a whole other feel and it goes to a whole new level. That's often when you realize that you're done.

What's the feeling when that happens—when you solve the conceptual problem, when the light bulb goes off and it all becomes clear?

Usually it's followed by spontaneous laughter, like getting the joke. ❑

A Three-Letter Word for Enjoyment



The first crossword puzzle, from [illegible] squares of the word. The answer to the first clue, "What bargain hunters enjoy" will begin in square #2, and end in square #3. The standard format of numbering clues under the headings "Across" and "Down" came some years later. You'll find the solution on page 34.

ARE YOU ONE OF THE 27 MILLION Americans addicted to the fiendishly clever invention of Arthur Wynne? Arthur who? On December 21, 1913, on the "Fun" page of the Sunday supplement of the New York *World*, Wynne published "Word-Cross"—the first modern crossword puzzle. (The name was inadvertently changed in an issue two weeks later by a less-than-accurate typesetter.)

Although Wynne's puzzle was well recieved, it took more than a decade for the crossword puzzle to catch on with the American public. But when it did catch on, people started filling in those tiny black and white squares as fast as they could be printed. By the mid-1920s, the heyday of the crossword, almost every newspaper in the U.S. carried at least one puzzle, and there were versions in most languages that could be read horizontally and vertically. In France, *les mots croisés* were all the rage. On Broadway, the musical "Puzzles of 1925" was a hit. People even wore crossword dresses and crossword jewelry as they stood around the piano belting out tunes like "Cross Word Mama" and "You Puzzle Me (But Papa's Gonna Figure You Out)."

It was quite a craze. By the end of 1924, six out of the ten books on the best-seller lists were crossword compilations. The first of these, *The Crossword Puzzle Book*, launched the succesful publishing company Simon and Schuster. The B&O Railroad supplied dictionaries on its trains for the convenience of puzzle-mad passengers. *Popular Mechanics* magazine ran plans for a "cross-word finder," a pocket-sized aid to "forming proper letter combinations without erasures on the puzzle chart." Robert M. Stilgenbauer labored for eleven years, from 1938 to 1949, to create the world's largest crossword puzzle—3185 squares across by 3149 down.

Eighty years after Arthur Wynne's pioneering effort, crosswords are no longer a fad—they have made an indelible mark on American culture. Although there are only about one hundred full-time cruciverbalists creating puzzles, more than fifty million people worldwide do crosswords every day, using up enough graphite to cover more than ninety acres of newsprint. (Only the most dedicated dare to do their puzzles in ink.)

Why are they still so popular? 1988 National Crossword Champion Doug Hoylman has one explanation: "In our daily lives, we deal with problems that have no definite answers.... In crosswords, there is always a right answer."

The Clues

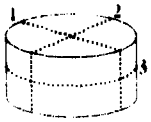
2-3 What bargain hunters enjoy.
4-5 A written acknowledgment.
6-7 Such and nothing more.
10-11 A bird.
14-15 Opposed to less.
18-19 What this puzzle is.
22-23 An animal of prey.
26-27 The close of a day.
28-29 Elude.
30-31 The plural of is.
8-9 To cultivate.
12-13 A bar of wood or iron.
16-17 What artists learn to do.
20-21 Fastened.
24-25 Found on the seashore.
10-18 The fiber of the gomuti palm.
6-22 What we all should be.
4-26 A daydream.
2-11 A talon.
19-28 A pigeon.
F-7 Part of your head.
23-30 A river in Russia.
1-32 To govern.
33-34 An aromatic plant.
N-8 A fist.
24-31 To agree with.
3-12 Part of a ship.
20-29 One.
5-27 Exchanging.
9-25 To sink in mud.
13-21 A boy.

Answers to Everything

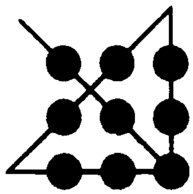
Answers to "Help! The Pig is in the Garden!"

More Than One Way to Cut a Cake (p.6)

Halve the cake with a vertical cut, quarter it with a second vertical cut; the third cut is horizontal, through the center of the cake, giving you eight equal pieces.



Dot to Dot (p.6)



A Glass of Water (p.7)

Pour the water from the second glass into the fourth glass. Most people don't think of pouring water from one glass into another. They assume that the water and the glass must move together.

Crossing the River (p.7)

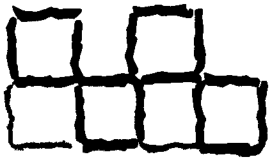
First, you take the chicken to the other side. Then you go back and get the dog. Then you leave the dog on the far side of the river and take the chicken back with you. You leave the chicken on the first side of the river and take the grain over. Then you go back and get the chicken.

If you're like me, you assumed that once you started taking things across, you never brought them back—a logical assumption considering that the goal is to get everything across the river, but one that trips you up in this case. Sometimes you have to take a step backward before you can move forward.

Dominos on a Checkerboard (p.8)

No matter how you place a domino, it covers one black square and one white square, since the squares alternate in color. But the two squares that have been cut away are the same color. That means you have more squares of one color than you have squares of the other color. Since there is no way to [illegible] you can't possibly cover the board.

Stick Squares (p.8)



The Racquetball Tournament (p.8)

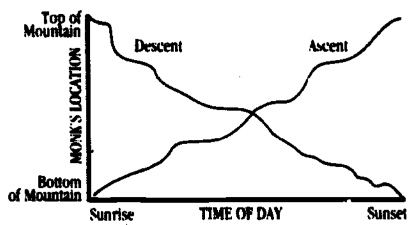
For a tournament with three players, you need two scorecards. For a tournament with five players, you need four scorecards. For a tournament with 205 players, you'll need 204 scorecards. To find the number of scorecards you need, just subtract one from the number of players in the tournament.

Chain Links (p.9)

Most people assume that they can open only the end links of each chain. Drawing a picture makes the

options clearer. You can open all the links in one chain, and use that chain to join the other three chains together.

Mountain-Climbing Monk (p.9)



This graph makes it obvious that the two paths must cross. Therefore, there must be a spot that the monk occupied at the same time on both trips.

You can take another approach to this problem. One heuristic suggests that if you can't solve the problem that you are working on, see if you can transform it into a problem whose solution you know. You can imagine, for instance, that there are two monks. One morning, the first monk begins walking down the mountain. At the same time, the other monk starts walking up the mountain. Obviously, they will meet along the path.

Sacks of Gold (p.9)

Divide the sacks into three groups of four each. Put four sacks on each side of the balance. If the two groups are equal, you know that the odd sack must be in the group that's not on the balance. Remove one of your groups of four "standard" sacks and replace it with the group that contains the odd sack. If the group with the odd sack is heavier than the standard group, you know the odd sack must be heavier than the standard sack.

Now set all your standard sacks aside, and weigh two sacks from the odd group against the other two sacks from the odd group. One of the pair of sacks that's heavier must be the odd sack. But which one? You can find out by balancing one of the sacks from the odd pair against one of your standard sacks. If the two sacks balance, then you know the sack that isn't on the scale is the odd sack.

Land of Liars (p.10)

Suppose both were liars. The first man would say he was a truthteller. The second would have to lie and say that his friend said he was a liar. Suppose the first was a truthteller and the second was a liar. The first would say he was a truthteller, but the second would have to say that he said he was a liar.

Suppose the first was a liar and the second was a truthteller. The first would say he was a truthteller, and the second would have to say that's what he said. But then the second, knowing the first was a liar, would not say that he was a truthteller.

The only hypothesis that fits is that both are truthtellers.

Full of Beans (p.10)

Suppose that all five of the random jellybeans were black. There would be five red jellybeans in the black jellybean jar and five black ones in the red jellybean jar, and the number of red beans in the red jar would equal the number of black beans in the black jar.

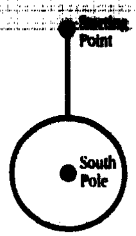
Suppose, by chance, all five of the random jellybeans were red. You'd end up with a jar of red jellybeans and a jar of black jellybeans, with equal numbers of beans.

Test the possibilities between these two, and you'll [illegible] numbers in the two jars.

Answer to "Homework Assignment #3"

[illegible]

Your starting point is any point 1.16 miles north of the South Pole. Why 1.16? Because that's one mile plus the radius of a circle with a one-mile circumference, which is 1/2π. [illegible] then one mile east. Walking one mile east takes you around the Pole in a circle with a circumference of one mile. Then you walk one mile north back to your starting point. If your starting point is 1.08 miles north of the South Pole, you will circle the Pole twice when you walk one mile east. From other starting points, you can circle the Pole three times, four times, and so on.



Answer to "Clowning Around" (p.15)

Key

Clowns are **A**ndy, **B**offo, **C**urly, **D**oofus, and **F**lippo

Stunts are **J**uggling, **P**ratfalls, **R**ubber Nose, **T**iny Cars, and **W**ater Balloons

Years are **88, 89, 90, 91, 92**.

∴ is "therefore." So A=R ∴ B, C≠R means: Andy has the Rubber Nose, therefore you can conclude that neither Boffo nor Curly has the Rubber Nose.

Items in bold type are true conclusions, the equivalent of a ● in the grid.

Clue #1

A=R ∴ B,C,D,F≠R; A≠92; A=R ∴ R≠92.

Clue #2

C=89 ∴ A,B,D,F≠89; A=R ∴ R≠89.

Clue #3

T=91 ∴ J,P,R,W≠91; R=A ∴ A≠91; B≠T ∴ B≠91; C=89 ∴ C≠T.

Clue #4

J=88 ∴ P,R,T,W≠88; C=89 ∴ C≠J; A=R ∴ A≠88; A≠88,89,91,92 ∴ **A=90**; A=R ∴ **R=90**; ∴ P,W≠90

Clue #5

D=W ∴ B,C,F≠W; C≠R,T,J,W ∴ **C=P**; C=89 ∴ **P=89** ∴ W≠89; W≠88, 89, 90, 91 ∴ W=92; D=W ∴ **D=92**; B≠R,T,P,W ∴ **B=J**; J=88 ∴ **B=88**; F≠88,89,90,92 ∴ **F=91**; T=91 ∴ **F=T**.

Conclusions

Andy, Rubber Nose, 1990
Boffo, Juggling, 1988
Curly, Pratfalls, 1989
Doofus, Water Balloons, 1992
Flippo, Tiny Cars, 1991

Answer to "Who-Dun-It?" (p.16)

Key

Order is **1**st, **2**nd, **3**rd, **4**th, **5**th

Weapons are **A**rsenic, **B**owie knife, **C**olt 45, **D**erringer, **G**arrotte

Sleuths are **H**olmes, **M**illhone, **N**etterfield, **P**oirot, **Q**ueen

Crooks are **R**ick, **S**ol, **T**om, **V**ic, **W**illy

Clue #1

S=A; ∴ R,T,V,W≠A

Clue #2

T≠B; H≠B; H≠T; T≠1,2; B≠1,5; H≠4,5.

Clue #3

R=3; ∴ S,T,V,W≠3; S=A ∴ A≠3.

N=1 ∴ H,M,P,Q≠1; T≠1,2 ∴ N≠T; R=3 ∴ N≠R; B≠1,5 ∴ N≠B. If H=1 then B=2; H≠1 ∴ B≠2.

Clue #4

Q=C; ∴ H,M,N,P≠C; Q≠1 ∴ C≠1; S=A ∴ S≠C ∴ S≠Q.

Clue #5

D≠W; D≠M; M≠W; M≠2; D≠4,5; W≠1,5; N=1 ∴ W≠N. If W=3, then D=2 and M=4; R=3 ∴ W≠3 ∴ D≠2 and M≠4.

Clue #6

W≠B

And now you get to the tough part. From the clues, you can also deduce the following:

D=1 or D=3 <u>and</u> H=2 or H=3.

If D=1 then W=2 and M=3. Since M and H can't both =3 ∴ D=1 and H=3 is impossible.

If H=2 then B=3 ∴ H=2 and D=3 is impossible.

If D=3 then W=4; if H=3 then B=4; B≠W ∴ D=3 and H=3 is impossible. ∴ **D=1** <u>and</u> **H=2**.

H=2 ∴ **B=3** and **T=4**.

D=1 ∴ **W=2** and **M=3**.

R=3; ∴ **3=R=M=B**.

D=1; N=1 ∴ **D=N**.

A≠1; S=A ∴ S≠1;W=2 ∴ S≠2; R=3 ∴ S≠3; T=4 ∴ S≠4 ∴ **S=5** ∴ **A=5**; **H=2** ∴ H≠A.

W=2, R=3, T=4 and S=5 ∴ **V=1** ∴ **1=V=N=D**.

H≠A,B,C,D ∴ **H=G**; H=2; W=2 ∴ **2=W=H=G**.

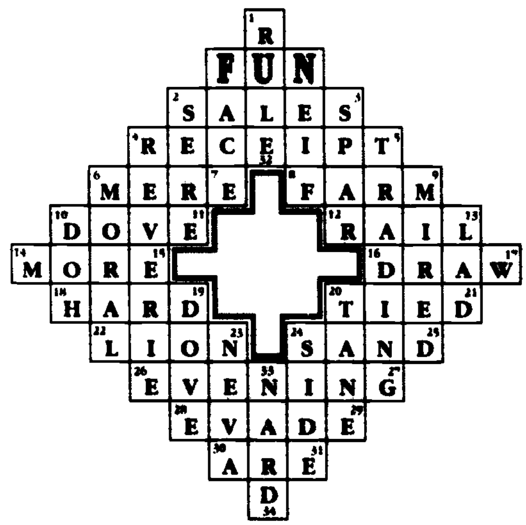
A=5, B=3, D=1, G=2 ∴ C=4; C=Q; T=4 ∴ **4=T=Q=C**.

P≠1,2,3,4 ∴ **P=5**; S=5; A=5; ∴ **5=S=P=A**.

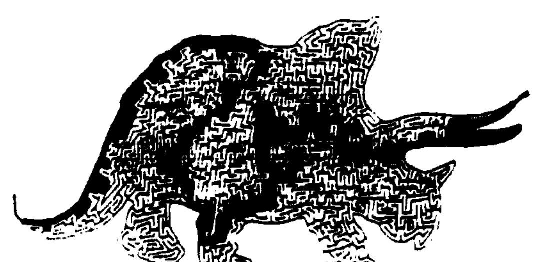
Conclusions

1st, [illegible], Derringer
2nd, Sherlock Holmes, Willy the Weasel, Garrotte
3rd, Kinsey Millhone, Rick the Stick, Bowie knife
4th, Tom Trouble, Ellery Queen, Colt 45
5th, Sleazy Sol, Hercule Poirot, Arsenic

Answer to the World's First Crossword Puzzle (p.32)



Answer to the Triceratops Maze (p.1)



[illegible] of our magazine topics leave [illegible] Is there a science topic you've always wondered about? Send your questions to "Ask Us," Exploring *Magazine, 3601 Lyon Street, San Francisco, CA 94123.*

Just how many different kinds of food products are made out of soybeans? How are they different, anyway?

—Robert Pincus
Seattle, Washington

A better question might be, what isn't made from soybeans? When people think of soybeans (if they do at all), they usually think of foods like soy sauce, tofu, miso, and soy milk. But these traditional foods account for a tiny percentage of the soybeans consumed in the United States. If you want to get a sense of just how hard it is to give an exact number of soy-based products, scan a few labels the next time you're at the supermarket. There are literally thousands of other foods made from soybeans or soybean derivatives.

Soybeans are legumes, and are related to green beans, pinto beans, and snow peas. They are known (by those in the know) for their versatility, high protein content, and high-quality oil. The hull of a soybean is high in fiber, and is used, for example, in bran breakfast cereals. The meat of the bean is filled with oil, which, according to Norm Chambers of the Iowa Soybean Promotion Board, accounts for seventy-five to eighty percent of the "vegetable" oil sold in this country. Soybean oil is also used in mayonnaise, salad dressing, coffee creamer, and margarine. After the oil has been pressed out of the beans, the remaining soy meal is usually fed to livestock, fish, and fowl as the protein component of their diet, or is used as a protein supplement in many processed human foods.

But, says Mr. Chambers, soybeans aren't used only in foods. There are soy inks, and scientists are working on soy diesel fuel. Soy products are used in adhesives, caulking compounds, pharmaceuticals, linoleum backing, paint, cosmetics, and fire extinguishers, to name but a few products. One company has even mixed soybeans and waste paper to make particle board that can look like granite. There's no word yet on how it tastes.

What effect does a magnet have on the [illegible] purple when our son placed a magnet against it. Is our TV radioactive beyond what should be expected?

—Dee Woodtor
Evanston, Illinois

If you want to see anything other than pretty colors on your color TV (say, programs, for example), you should keep magnets away from it. If you leave a magnet on the screen, it will permanently magnetize the screen, and purple will be the predominant color on the whole screen, all the time.

If you turn on your TV and look closely at the screen, you'll see that the picture is made up of many tiny red, green, and blue dots. These dots glow red, green, or blue when they get hit with electrons (negatively charged atomic particles). A tube in your TV fires beams of electrons at the screen, and a magnetic field directs the electrons to the proper dots. The red, green, and blue light from the dots mixes together to form the color picture on your screen.

When your son places his magnet near the TV screen, the magnet redirects the electrons heading for the screen to the wrong dots, so that the red, green, and blue light mix together to produce odd colors. That's why you see purple. At first, that purple tint will appear only where the magnet is close to the screen, but eventually the magnet will permanently magnetize certain metal parts in the screen and the discoloration will be yours forever.

No matter what color you see on the screen, your TV is emitting no beta or gamma rays, and very few X-rays, the types of radiation we usually refer to and think of as dangerous. The electricity that runs your TV, the signals it receives, and the light it gives off are all forms of electromagnetic radiation. Electromagnetic radiation takes many forms, from sunlight to radio waves to microwaves and more. But even if you permanently magnetize your TV screen, it won't emit a harmful amount of radiation.

—Nic Sammond

Tools and Toys

[illegible] than learning to tie my shoes) was on the back page of the Sunday comics. I loved the dot-to-dot puzzles, scrambled words, and pictures of pastoral gardens where various objects (scissors, a boot) were cleverly hidden. But once my sister Shirley learned to read, the competition for the comics got fierce, and I moved on to other sorts of diversions, like crossword puzzles and a math book full of story problems.

I liked story problems (actually, I still do), but I've always preferred books of games and puzzles to textbooks. ***Brainteasers and Puzzles for Kids*** **(Watermill Press, $1.95)**, is a little book of over one hundred puzzles—logic, math, pictures, even riddles—that are easy enough for kids to solve, but just tricky enough to keep parents entertained, too. ***Brain Puzzles*** **by Jenny Tyler (EDC Publishing, $4.50)** is another good source of puzzles for the beginning problem solver, with colorful cartoon illustrations, and a very useful hints section at the back that helps kids learn how to figure out the puzzles that perplex them. ***Visitors from the Red Planet (and 76 other solve-them-yourself mysteries)*** **by Dr. Crypton (W. W. Norton, $7.95)** is a collection of devilishly clever, and delightfully odd one-page teasers that will challenge even the geniuses in your family. And for the true conundrum connoisseur, ***Puzzlegrams*** by **Pentagram (Simon & Schuster, $15.99)** is a big, beautiful full-color book of puzzles and brain teasers. (Also recommended are their ***Pentagames*** and ***Pentamagic***.)

The Private Eye **(Private Eye Project, $21.95)** is another item I would love to have had when I was in school. It's a workbook designed to help students (K-12) develop hands-on investigation skills, concentration, observation, creativity, and scientific literacy. Not only that, it's big fun. The book comes with a magnifier that allows the user to examine the minute details of anything within reach. In a series of interesting, playful experiments and suggestions, the book guides readers to use the magnifier to observe details, to deduce conclusions, and to theorize and question their observations—in other words, to develop the skills needed to solve just about any problem.

Another approach to seeing more clearly and breaking through mental blocks is the deck of ***Oblique Strategies*** **cards (Opal Information,** P.O. Box 141, Leigh-on-Sea, Essex, UK, $35) [illegible] good way to shake up your creative process.

Since there weren't any computers when I was a kid, my sisters and I learned our strategies from board games, which didn't talk or move or anything. Boy, we didn't know what we were missing. ***Putt-Putt Joins the Parade*** **(Electronic Arts, $35 for IBM; Mac version available July 1993)**, is "edutainment" software which encourages 3-7 year-olds to use simple logic and critical thinking. Putt-Putt is an adorable animated car that the child can move through a full-color world using a mouse or joystick. Digitized speech and great sound effects make Putt-Putt seem very real, and solving his problems (rescuing a puppy, getting a cow out of the middle of the road, shopping in a toy store) are bound to fascinate any kid. Putt-Putt's dilemmas are simple, but I'm 39 now, and I played the game for more than an hour, exploring Cartown and trying to get Putt-Putt out of jams.

I spent a happy hour with Putt-Putt, but I spent all day with ***SimLife***. If you consider the survival of the planet the ultimate problem, then ***SimLife*** **(Maxis, approx. $50; Mac or IBM)** is the ultimate problem-solving game. You can create a world, populate it with a variety of plants and animals, determine the climate and the terrain, and sit back and watch what happens. Beings procreate, predators eat their neighbors, species propagate or become extinct. The game comes with a very good tutorial that teaches you the fundamentals; after that, there are few limits to what you can do. (When all my anteaters were eaten by flying dragons I made the dragons fruitivores.) Advanced players can tinker with genetic engineering, climate control, even change the laws of physics!

Hey Shirl, you can have the comics.

—Betsy McGee

Most of these puzzles and brain exercises are available at the Exploratorium Store at 1-800-359-9899, or at your local museum store. ❑

Related Reading

Help! The Pig is in the Garden! by Pat Murphy

The Complete Problem Solver by John R. Hayes. Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1989. A textbook for a course on general problem-solving skills.

The Five-Day Course in Thinking by Edward de Bono. Basic Books, Inc., New York, 1967. A book of exercises to stimulate ideas about thinking.

The Ideal Problem Solver by John D. Bransford and Barry S. Stein. W.H. Freeman, New York, 1984. A guide for improving thinking, learning, and creativity.

More Games for the Super-Intelligent by James F. Fixx. Doubleday and Co., Garden City, New York, 1976. Math, logic, and word puzzles with insights into the minds of masterminds.

The Teaching of Thinking by Raymond S. Nickerson with D. Perkins and E. Smith. Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1985. A textbook for a course on thinking skills.

The Case of the Smoking Brain by Ellen Klages

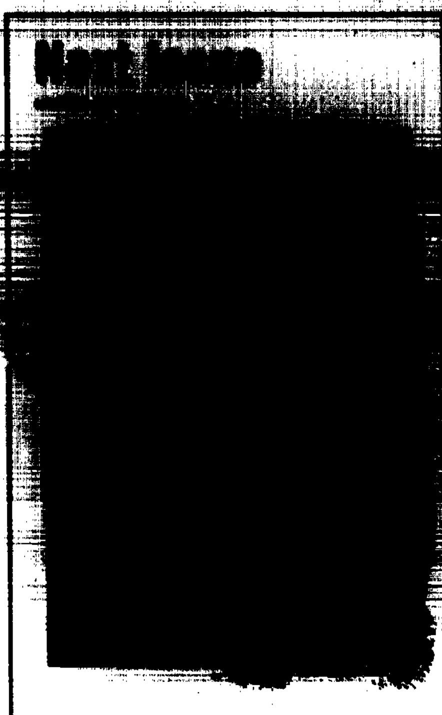
Original Logic Problems, published by Penny Press, Norwalk, CT. A bi-monthly magazine featuring more than eighty logic puzzles, ranging from the relatively simple to conundrums that will make smoke pour out of the average person's brain.

Sherlock Holmes: The Complete Novels and Stories, Volume One by Sir Arthur Conan Doyle. Bantam, 1986. A paperback compilation of two novels and thirty-six short stories featuring the greatest fictional detective of all time.

Symbolic Logic and *The Game of Logic*, by Lewis Carroll. Dover, 1958. A two-in-one volume of Carroll's "mathematical recreations." The nonsense syllogisms are fun; the discussions of logic theory are quite challenging.

A Dialogue of Questions by Adam Frank

Discovering by Robert Scott Root-Bernstein. Harvard University Press, Cambridge, 1991. ❑



What happens when you turn out the lights?

In our next issue we go exploring In the Dark. Discover the world of nocturnal animals, the curious ways your eyes adapt to the dark, what really happens inside the Exploratorium's Tactile Dome...and more.

Credits & Acknowledgments

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