PROBING THE CREATIVE MIND

In the shimmering heat along the Olduvai lakeside in ancient Africa, an anonymous ancestor picks up a sharp rock. He runs his fingers across its jagged edge and wonders if it will scrape meat from the bones that lie at his feet. Nearly two million years later, Deana Ward, age four, handles a very different rock—one that humans have brought back from the lunar surface. One that has been smoothed by the touches of countless children's hands. Deana ponders her rock too, perhaps not so differently from that earliest human. She wonders when and how she might visit the moon.

Stone tools and moon rocks are greatly separated in time and distance, but between them stretches the continuous thread of human creativity. The progress that moved us from the Olduvai lakeside to the moon and beyond is testament to a simple fact: the human mind is designed to create. Underlying all we achieve, as individuals and as a species, is an elegant

machine—a mind with an enormous capacity to make use of our experiences and to produce new ideas.

This book is about that machine. What are its basic elements? By what principles does it operate? How does it take the raw materials of experience and transform them into creative thoughts?

How does the mind leap ahead to stagger us with brilliant achievements in science, the arts, and technology? How does it satisfy us so thoroughly with handy solutions to our problems? How does it sometimes become mired in past mistakes, and leave us trudging along through the same old ruts? Most importantly, how can we fine-tune it so that we can leap more and trudge less?

We will see that answers to these important questions are beginning to emerge from careful scientific studies of the mind, conducted in the field of cognitive psychology. Before looking for those answers, however, let's take a brief excursion through the importance of creativity in our lives, our creative heritage, and some different ways of thinking about creativity.

OUR CREATIVE NEED

Creativity plays a vital role in a host of human activities. It can enrich our lives when it reveals itself in soothing or exhilarating music, breathtaking or shocking paintings, joyous or sobering movies, and thought-provoking or titillating novels. It can bring us new tools that eliminate the drudgery of mundane chores, and new toys or gadgets to amuse and entertain us. It can provoke advances in science and medicine, and it can provide great personal satisfaction. Understanding and fostering creativity, then, can certainly enhance our lives, and it can even help save lives.

Aside from its obvious role in spurring musical, artistic, and inventive achievement, creativity is essential to solving a wide range of problems. As a society, we face an enormous number of

complex problems that demand creative solutions. We must find cures for deadly diseases, such as cancer and AIDS, and solutions to pressing global concerns such as hunger, poverty, and violence.

As individuals, we also face challenges, ranging from the trivial to the monumental, from breaking into a soda can whose pop-top device is defective, to searching for meaning in our lives. These challenges are not on as grand a scale as societal problems, but they too can benefit from creative thinking.

Creative thinking is also crucial as we adapt to our changing world. We must cope effectively with continual changes in our work situations and in our personal lives if we are to continue participating actively in society. By one estimate, for instance, the typical worker in the United States will change jobs eight times. The days of sticking with the same job in the same stable company for all of one's working life are over. Change is the norm. What this means is that most workers will be unable simply to learn a single set of habits or skills that they will perform throughout their careers. They will have to cultivate innovative ways of responding to interminable changes in their lives.

Continual changes in the world around us also force us to confront novel situations, even if we keep the same jobs. Spurred by numbingly rapid advances in computer technology, the ways in which we communicate with one another, purchase products, and find information are all undergoing persistent, radical change. We must constantly contrive adaptive strategies to contend with these changes.

On a broader scale, corporations also must adapt to changing market conditions if they are to remain competitive. U.S. corporations in particular have lost ground to international competitors over the last 20 years, and are sorely in need of innovative solutions.[1] Consequently, knowing how to enhance innovative thinking is crucial to their continued economic growth and competitiveness in the global marketplace.

Finally, in the largest sense, whole societies also must realign and redefine themselves now that the central structuring

force of the last four decades, the Cold War, is behind us. How imaginatively we resolve these issues will determine our likelihood of living together peacefully.

We do not pretend to hold the answers to all of the challenges that confront individuals, corporations, and societies. We do believe, however, that humans will continue to solve such problems, because *it is in our nature to be inventive*. We possess the requisite mental tools to be creative, even though we may not always wield them as effectively as we could.

We may be able to hone our mental skills to cope more inventively with challenging problems, or to behave more creatively in any number of arenas, such as music and art. Identifying the fundamental principles of creative thinking will help us accomplish these lofty goals. Because creative thinking underlies successful problem solving in general, unveiling its secrets may prove beneficial to solving any one of the individual problems. Further, by laying bare these principles, we will be in a position to prepare people more constructively for the future.

OUR CREATIVE NATURE

Shortly after that first human ancestor picked up a sharp rock and pondered its usefulness, *Homo habilis* began to fashion their own primitive stone tools by chipping away at ordinary rocks to sharpen them. By crafting their own tools, these early humans freed themselves from depending on the good fortune to find a suitable rock, and began to make their own luck. This seemingly simple act of creation was a first step on the path toward ever more advanced creative inventions, insights, and discoveries, and it set us apart from the rest of the animal kingdom. More than any other trait, it is our creativity, expressed through invention, language, art, music, science, and technology, that makes us uniquely human.

Homo habilis used stone knives to cut meat from the bones of other animals. Through successive generations, their descendants crafted ever more sophisticated stone tools for acquiring and preparing food. Comparatively recently, beginning in about 4500 B.C., we learned to form copper, then bronze, then iron and steel into a wide variety of tools. More recently, of course, we have invented the Swiss Army Knife, electric knives, and food processors.

This sequence of progressive change is repeated in many spheres of human activity. For instance, early humans surely looked up in wonder at the heavens. Their early curiosity was supplanted by the first systematic observations in ancient China, Egypt, and Mesopotamia, and these observations, in turn, gave way to more detailed celestial charts (570 B.C.), and to innovative instruments such as the astrolabe (130 B.C.) and the telescope (1608 A.D.).[2] Along the way, we accepted the view of the Earth as a sphere rather than a flat surface, and as one of many celestial bodies in motion rather than as the stationary center of the universe.

Now, of course, we scan the skies with giant optical telescopes and radio astronomy, we have set foot on the moon, and we have launched probes to the planets in our solar system and beyond. We now regularly peer down at ourselves from satellites, rather than merely gazing outward into space.

Consider just the last two centuries and the multitude of talented people who shaped our world through their well-known accomplishments in science, the arts, and technology. To note just a few, Darwin put forth his revolutionary theory of evolution, Kekule envisioned the elegantly simple nature of the benzene ring, Einstein formulated his mind-bending theory of relativity, and Crick and Watson identified the graceful, double-helical structure of DNA. Monet and the French Impressionists found a vivid new way to depict the world, Stravinsky composed his alternately raucous and serene *The Rite of Spring*, and Jules Verne anticipated exhilarating breakthroughs in space exploration, such as the Apollo moon landings, through brilliantly conceived fiction. In addition, determined innovators such as Thomas Edison, the Wright brothers, and Seymour Cray brought

us a host of world-changing inventions, such as the light bulb, the airplane, and, more recently, the modern supercomputer. All of these familiar yet earth-shaking accomplishments are clear examples of creativity, but they seem to be quite different from one another. Can we explain them all in the same way? Do the minds of the celebrated people who accomplished these amazing feats work differently than ours? We think the answers to these two questions are "yes" and "no," respectively, and we will try to show why.

Our contemporary world is also teeming with the products of creativity. Inventiveness is all around us today. Consider, for example, that the U.S. Patent Office alone issues about 70,000 patents each year. In fact, George Basalla, a historian at the University of Delaware, used patent statistics to make the case that there is as much diversity in the set of things made by humans as in the set of living things on Earth.[3]

Furthermore, patent statistics capture only a small portion of the devices people actually invent and fabricate. And they miss entirely all of the songs, books, paintings, and scientific theories people create.

But, creativity pertains as much to the ordinary as it does to the extraordinary. While dramatic discoveries are being made and revolutionary inventions are being fashioned, ordinary people encounter problems in their daily lives that also call for creative solutions. For instance, Lola Lopes faced a problem when she needed to remove and repair her car's fuel pump. The peculiar arrangement of her engine parts had the fuel line running downhill into the pump. Consequently, if she extracted the pump, gravity would blithely do its allotted task and drain Lola's gasoline all over her driveway. How was she to plug up the fuel line?

As we will find, Lola devised a highly creative solution. The path she trekked to reach her solution tells us a great deal about how to overcome blocks to everyday creativity.

Lola's case is not an isolated one. Millions of people have, in fact, found imaginative ways to cope with problems in their daily lives, such as spreading butter or cutting cheese without a

knife, opening a reluctant twist cap without a bottle opener, finding a subtle way to persuade another person, concocting an original recipe to make spaghetti more interesting, or working out a technique for keeping children entertained on a long car trip.

When we fasten curtains closed with a safety pin, substitute a paper clip for a key chain, or wrap Velcro straps from worn-out handball gloves around pant legs to keep them from being ensnared by a bicycle chain, we are being inventive. When we dream up different words to lampoon a familiar song, spin personalized fairy tales for our children, or paint or write stories for our own pleasure, we are being creative.

These observations reinforce the point that humans are essentially a creative species. This simple statement carries with it a striking implication that forms the central thesis of this book: creativity arises from ordinary mental processes that are part of the daily cognitive repertoire of normal human beings. An earlier observer put it more bluntly: "It would appear that genius is not at all a divine and rare gift. . .but is the destiny of everyone who has not been born a complete idiot."[4]

This blunt statement is too extreme, but it underscores a key point. The fundamental processes we need to be creative exist within all of us.

Being creative is such a natural part of being human that we can view creativity much the way we view language; no human cultures, no matter how isolated, have ever been found that do not use language. The same may be said of creativity. Of course, some cultures may boast more extensive technological, scientific, literary, or artistic accomplishments, but this depends on the relative value societies place on innovation, not differences in the basic mental processes of which people are capable.[3]

Since creativity is an intrinsic capability of ours, why are we often stumped by difficult problems that cry out for more creative solutions? We have claimed that humans are, by nature, creative thinkers who constantly rise to such challenges. Why do we sometimes have such trouble doing so? Answering these questions provides telling insights into the nature of creativity.

First, even though many people handle their relatively simple everyday problems creatively, many real-world problems are so complex that the path to a creative solution is more obscure. Finding a way to spread butter without a knife is, after all, simpler than discovering a way to produce large quantities of DNA from a small sample. Understanding the principles by which the creative mind operates, however, can help thinkers to ferret out even these more well-hidden paths.

Second, many people fail to take advantage of their creative potential, even in attacking simpler everyday problems. They are perfectly capable of using the basic mental processes that underlie creativity, but do not always see how to do so. They possess what might be called *latent creative potential*. By identifying what others do when they achieve creative solutions, it is possible to help people live up to their creative potential.

Finally, as we will see shortly, even obviously creative solutions to problems are not always as innovative as they could be. Strikingly creative advances often incorporate what in retrospect are fairly obvious limitations. By understanding the processes that lead to new ideas, we can help to make creative ideas even better.

THE CREATIVE COGNITION APPROACH

Our approach to creativity provides answers to some of the most basic questions about creativity: What brings it about? What inhibits it? How can it be enhanced? We call the approach *creative cognition* because we adapt the scientific theories and procedures from modern cognitive psychology to better understand and heighten creativity.

Creativity has for centuries remained a nearly impenetrable mystery, and it may seem surprising that it would yield its secrets to a scientific method of inquiry. However, cognitive psychology itself is a science that has already successfully probed many of the enigmatic workings of the human mind, and

we have simply extended its methods into the realm of creativity. Cognitive psychology focuses on how people interpret the world around them; how they accumulate knowledge, organize their experiences, and recall memories; how they put their knowledge to work to make important decisions and solve problems from the simplest to the most complex; how they consider and plan for the future; and how they carry out actions from as basic as walking to as complex as piloting a supersonic aircraft.

By formulating theories and rigorously testing their predictions in carefully controlled laboratory experiments, cognitive psychologists have unlocked many of the mysteries of human knowledge and thought. Our central assumption is that the same scientific approach can help us to unveil the secrets of human creativity, because creativity is based on the same kinds of cognitive processes that we all use in ordinary, everyday thought: retrieving memories, forming mental images, and using concepts—the very processes that cognitive psychologists have learned so much about. We simply execute those processes differently when we act creatively.

Creativity is one of our most impressive abilities, and it often evokes strong emotions. When you do something creative you feel good. When you ponder great scientific and artistic accomplishments you have a sense of excitement and wonder.

But creativity is not entirely mysterious. Using the methods of creative cognition, we can better understand how the intricate workings of the human mind bring it about. And, like a spectacular sunrise or the birth of a child, the creative process is no less inspiring for being understandable.

THE FOUR P'S OF CREATIVITY: PRODUCTS, PEOPLE, PRESSURES, AND PROCESSES

Because creativity can thrill us with its great accomplishments, and because it is essential for solving practical problems, it has been studied in many ways. In this section, we show how our

creative cognition approach complements those other ways of thinking about creativity.

PRODUCTS

A traditional way to approach creativity is to try to specify what counts as a creative product. What properties must an idea, a work of art, a piece of music, a problem solution, an invention or discovery have in order to be considered creative? Almost everyone would agree on two criteria: *appropriateness* and *novelty*. The idea must yield a workable solution to some relevant problem,[5] and it must be original, at least in the mind of the creator.

The first criterion is obvious enough. After all, if we ask you "how much is two plus two?" and you say "spaghetti," your answer is remarkably original, but not very helpful. We would not deem it to be creative. Only if a novel idea begets a useful invention, a valid discovery, a cure for a disease, an emotional response through art or music, or some other accomplishment would it count as creative.

The criterion of novelty, however, deserves further comment. Nobody would dispute the statement that there must be something new about an idea for it to be creative. The problem with focusing on novelty, however, is that it can mislead us into thinking that creative ideas are *only* novel. In reality, however, the ways in which creative ideas resemble old ideas are just as important as the ways in which they differ.

To see this point, consider the truism that the rate of scientific and technological change continues to accelerate. It took over one and a half million years to progress from stone to metal knives, but less than seven thousand years to advance from the first metal knives to the first electric ones. This implies that new ideas are constantly being built on the foundations of older ones.

What we call innovative ideas are never completely novel. They are always a marriage of old and new. To fathom creativity,

then, we have to examine not just how new ideas break with the past, but how they carry it forward. Doing so demands that we probe the nature of human knowledge and how it is used. This is where creative cognition comes in.

Throughout this book, we will focus on this central theme. What can cognitive science reveal about the nature of creative ideas? How are they original, how are they familiar, and what determines the balance between these properties?

PEOPLE

A second traditional approach to creativity emphasizes differences between people. In this approach, some people are judged inherently more creative than others, and there is little one can do to improve one's creative standing. An extreme version of this individual differences approach, called the "genius view," holds that some people come into the world endowed with an enormous creative capacity. Their minds are assumed to work differently from those of ordinary humans. They experience flashes of insight in which scientific discoveries, whole works of poetry, complete symphonies, and so on, come to them unpredictably. They may or may not be able to identify the source of their own ideas. And all that's left for the rest of us is to observe and be moved by their accomplishments.

Many have attacked the "genius view," especially its assumption that creative ideas spring forth from obscure and unpredictable sources. Robert Weisberg, for example, a noted creativity expert at Temple University, has traced the origins of a wide range of highly creative accomplishments, including Edison's wizardly inventions, Picasso's evocative paintings, and Watson and Crick's illuminating discovery of the structure of DNA.[6] Weisberg has demonstrated that they all emanated from a deliberate application of previously acquired knowledge, not some mysterious, unobservable processes.

Research focused on the lives of acknowledged geniuses does help us to keep in mind the heights to which people can

rise. Indeed, some excellent recent treatments along these lines allow us to celebrate the accomplishments of some of the world's most noted innovators[7,8] Certainly we should honor and revere their deeds, and we can all be inspired by them. We can also try to learn how to improve our own thinking. If we examine what extraordinarily creative people do, perhaps we can learn to emulate them.

It is also vital and empowering, however, to focus on the genius. . . . or at least the potential genius, in all of us. Thus, we are concerned more with what people have in common than with how they differ. We can celebrate the extremes of creative achievement—the stunning brilliance of Mozart's symphonies or Einstein's theory of relativity—without denying the potential that we all share. We also can examine why some people behave more creatively than others, and why some achieve results that dazzle and uplift us. Most importantly, we can assess how each of us might move toward our highest creative potential.

As we will find, individual differences in creativity are based on the amount of knowledge people accrue, and the ways in which they judiciously apply and reject that knowledge. The differences are not based on "divine inspiration," or some set of inexplicable mental abilities available only to the Einsteins of the world. Why do we say this? Because of the simple fact that we are all human, and as such, we are much more alike in our cognitive abilities than we are different. The mind of every reader of this book is much more similar to Einstein's than to that of the most creative member of the most creative nonhuman species. We all possess a human brain, descended in some way from that first tool maker, and capable of carrying out roughly the same basic mental processes of storing, retrieving, considering, and combining information.

Our approach is at once hopeful and challenging: hopeful because it encourages those who say, "I'm just not very creative," to reconsider their potential, and challenging because it forces those who see themselves as creative to recognize that their creativity derives from cognitive skills that they deliberately exercise, not from the sheer luck of having been born creative.

PRESSURES

Clearly, external pressures can motivate us either to cultivate or to quash creative ideas, to share them with other people or to keep them to ourselves. Several noted thinkers have provided in-depth treatments of these pressures,[9] and we acknowledge their significance in fostering or inhibiting creativity. It does a person no good to know how to be creative if he or she is constantly in a situation that discourages creativity. Nevertheless, our primary focus is on the creative workings of the human mind itself, rather than on those external pressures.

PROCESSES

Our approach to mapping the territory of creativity concentrates on the immense bodies of knowledge we all carry around in our heads, and the basic operations the mind performs on that knowledge. Although many factors influence creativity, knowledge and the processes that manipulate it are the fundamental materials from which we form creative ideas. Knowledge is the bricks and mortar, the wood and nails. Processes are the tools—the hammers, saws, and trowels. Creative thoughts are the houses we build and dwell in.

GENERATING IDEAS AND EXPLORING THEIR CREATIVE POTENTIAL

Many creative activities can be broken down into two phases. First, a person generates an idea, and second, the person explores the creative possibilities of that idea. Some of these ideas may be generated deliberately, and others may arrive unbidden. When explored, some of the ideas will be found to be silly or unworkable, but others will yield important advances.

In a way, creativity resembles evolution. Many variations of ideas, like the variations of traits in a species, originate from combinations and mutations of what has come before. When

tested or explored against the demands of the environment, some variations fail miserably and are not passed on. Some new ideas fail to move us or solve our problems, just as some traits reduce a creature's chance of survival. Other variations convey some distinct advantage. They advance us. They survive. Importantly, however, *creative cognition* provides a way to increase the creative potential of newly spawned ideas, much as genetic engineering attempts to improve on evolution by deliberately designing species that are more adaptive.

The history of invention and discovery is brimming with examples of this generate-and-explore process. Many people have reported receiving flashes of insight, and then seizing on those insights to exploit their full potential. For example, while dozing by the fire one evening in 1865, the famed chemist Friedrich August Kekulé beheld an image of a snake swallowing its own tail. When he explored the significance of that unconsciously generated form he came to the creative discovery that the benzene molecule is shaped like a ring. Until that time, organic chemists had assumed that all carbon-based molecules must be made from carbon units linked in a series or chain. This notion limited the molecular arrangements they considered, and led to a nagging mystery about the actual nature of benzene, which could not fit any known chain. Kekulé's dramatic vision allowed scientists to overcome this inhibiting idea, and it provided a foundation for modern organic chemistry.

Of course, there is no guarantee that newly hatched ideas will prove fruitful. Many people have had apparent insights that turned out to be wrong on further consideration. We tend to forget these failures, and history seldom records them. But they do show us that scrutinizing ideas to test their usefulness is as critical to creativity as initiating the ideas in the first place.

Creative ideas do not always spring themselves on an unsuspecting thinker in the dramatic and seemingly unconscious way that Kekule's snake did. Nor do we have to wait around for an insight to pop into our mind. Instead, we can gain control of the creative process by deliberately inducing ideas that have creative potential. When Lord Rutherford considered the

possibility that the structure of the hydrogen atom resembles the structure of a planetary system, his idea did not leap upon him unbidden in a dream. Like Kekulé's insight, however, Rutherford's was a powerful idea that provoked much research.

The model of creativity we call *Geneplore* captures the two phases of generation and exploration.[10] By separating creativity into these two phases it is easier to isolate some of the mental processes that are involved and determine how to wield them most effectively. For example, by exploiting simple mental activities such as recalling information, combining concepts, and crafting analogies, one can bring to life ideas that may lead to unexpected and penetrating insights. One can then probe these ideas by using other simple processes such as interpretation, inference, and searching for limitations.

The Geneplore theory tells us that, to be creative, we should generate ideas with creative potential and then explore them. But how are we to do this? Coming up with creative ideas may seem a mysterious process open to only a few special individuals, but, in fact, all of us are capable of developing truly interesting and novel ideas. We simply have to exploit, in a different way, some of the basic cognitive processes that we use all the time. What follows is an account of how our thinking can sometimes produce good, creative ideas, and sometimes fixate us on old ideas. Knowing how to use basic mental processes to do the former and avoid the latter is what being creative is about.

THE IMPACT OF OLD IDEAS ON NEW ONES

Mr. Speer was a conductor for the Paterson Railroad. On a warm September evening in 1835 he was sitting on a railroad car as it approached the Paterson depot. When an axle broke, he was thrown off the car and crushed to death under its weight.

Why was Mr. Speer seated atop a moving train car rather than safely inside it? Was he just being reckless, taking a risk to enjoy the warm summer air? No. According to the newspaper

account he was "a very industrious and sober man," not prone to recklessness:

> Accident.–As the locomotive on the Paterson Railroad, with a train, composed of transportation and passenger cars, was approaching the depot at Paterson, on Monday evening, an axle of the leading transportation car gave way, which overturned that and the next car, and threw the third off the track. The locomotive and passenger cars remained upon the track uninjured, though the passengers felt a shock by the concussion. Mr. Speer, the conductor of transportation, a very industrious and sober man, was seated *on* the car at the break, and unfortunately was crushed to death under the load. [emphasis added]—*American Railroad Journal*, 1835

Mr. Speer sat on the car because a basic flaw in the design of early railroad cars required him and his fellow conductors to ride outside. That design flaw is a good place to start because it sets the backdrop for depicting both the positive and negative influence of old ideas.

As detailed in John White's classic, *The American Railroad Passenger Car*, early train cars were almost direct replicas of stagecoaches, complete with running boards and brakes that were operated by a conductor seated atop the vehicle in the front.[11] An example of one of these cars is shown in Figure 1.1. Like stagecoaches, they did not have central aisles between the seats. The design forced conductors and baggage handlers to climb all around the outside of the cars to do their jobs. And they rode on the outside all the time, even though this was clearly unsafe. Consequently, many of them fell off and were killed. This is what happened to Mr. Speer.

Only later did car designs incorporate central aisles through which railroad employees could walk more safely. Even though they were safer, these new designs met with some resistance. In fact, some people worried that the central aisle would become one long spittoon.[12]

Railroads are such a familiar part of our world today that it is easy to miss an important aspect of this example. In the 1830s

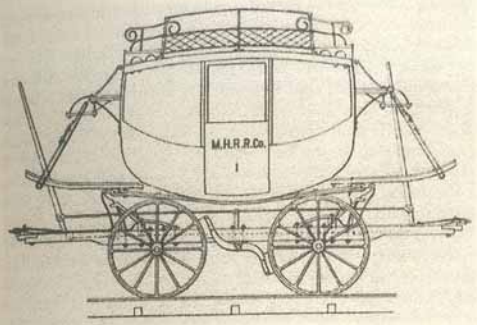

FIGURE 1.1. Example of early railroad car resembling a stagecoach (adapted from White, 1978).

the railroad was a striking technological advancement that was poised to revolutionize the way people traveled. So, adhering to old ideas from stagecoaches happened in spite of the fact that rail travel was an enormously creative idea. The point is a very general one: even plainly imaginative ideas tend to be heavily influenced by the old ideas that have preceded them.

There are many other examples of how imagination is influenced by what we already know. For instance, early forms of automated mining equipment duplicated the action of a person swinging a pick, and only later gave way to the more efficient continuous belt design. More recently, the fact that many modern computer terminals display exactly 80 columns of text is a direct outgrowth from the era when we literally fed data into computers by way of 80-column punch cards. A quick survey of science fiction will also convince you that most space aliens preserve many of the features of animals on Earth. Even serious speculative science shows how existing knowledge can

guide or constrain the shape of new ideas. For instance, Frank Drake, the noted astronomer involved in the Search for Extraterrestrial Intelligence (SETI), believes that intelligent creatures from other planets will look basically like humans. Although such creatures could take virtually any form, even our scientific imaginations tend to consider only certain possibilities. Indeed the entire SETI project is based on the idea that intelligent beings somewhere else in the universe will be pretty much like us, including the way they communicate. This might be seen as just an interesting quirk were it not for the fact that we have spent millions of dollars on such projects.

Why do new ideas often look so much like old ideas? The answer is simple. When you develop an idea, you tend to recall something you are familiar with and pattern the new idea after that. The result is that many features of old ideas crop up in new ideas even when those features are unnecessary and potentially dangerous. We call this phenomenon *structured imagination*, and it colors the thinking of designers, scientists, business people, and artists alike. Indeed it influences each of us. It can lead to deadly consequences as we've seen in the case of engineering design, to failed businesses when corporations adhere to old procedures rather than searching for innovative ways to stay competitive, and to inhibited creativity in people as they face everyday situations and strive to fulfill their goals.

Sometimes we need to overcome old ways of thinking to achieve better solutions. Let's now return to Lola Lopes and her fuel line for an everyday example of moving beyond standard interpretations of objects in the world. Have you thought of a solution yet? Her path to a solution is an informative one, and you may have followed a similar line of reasoning. She first considered objects designed to perform a standard *function*: plugging holes. She wanted to find something to put *into* the end of the fuel line. Nothing she thought of would fit. Then she contemplated standard means of sealing things such as aluminum foil and plastic wrap, but none of these seemed workable. Finally she hit on the solution. She jammed the end of the fuel line into a potato. It wedged in nicely, formed a tight seal, and allowed her to get on with her repairs.

Lola had to get away from thinking about objects that normally plug into openings to envision what else could possibly do the job. She had to consider plugging the fuel line into something rather than vice versa. And, she certainly had to escape from the most typical uses of potatoes to realize that one could serve as a seal for a fuel line.

At the same time, however, we do not want to reject the past completely. Basing new ideas on old information can also convey distinct advantages. The details of stagecoach designs provided an expedient way of getting rail travel off and running. The properties of Earth animals furnish science fiction authors with a way of depicting space aliens so that audiences can readily comprehend them. The dramatic advances in simple tools and space exploration that we alluded to earlier occurred because people used old ideas as a springboard for new ones. Even Lola had to consult her knowledge about the properties of potatoes to know that one might solve her problem.

Creative ideas, then, typically emerge from a skillful blending of old and new information. Being creative demands that we judiciously employ and reject earlier knowledge. How can we identify the features of old ideas that we should retain and those that we should discard? Can we recognize when it might be good to deliberately use old ideas and when it would be better to try to avoid them entirely? To answer these provocative questions, we must plumb the very nature of human knowledge.

METACOGNITION: TAKING CONTROL

If creativity can result from applying ordinary mental operations in special ways, then being creative demands that we take charge of our own ideas. To do so, we have to practice the art of monitoring our own thinking, called *metacognition*.

Paying attention to what's going on in our own minds is not really all that difficult. Indeed this form of standing outside ourselves and looking in comes quite naturally in some circumstances. Most of us have had the maddening experience of knowing just the word we're looking for but being unable to pluck it out of the mists of our mind. It taunts and tantalizes us, but it will not come out in the open. And we are certain that if we hear the word, we will recognize it instantly. Being able to examine our knowledge this way is a form of metacognition, just as its embarrassing cousin: seeing a familiar face and being temporarily unable to recall the person's name.

We know that people who monitor their understanding of what they read tend to be better readers. When they bump up against confusing material, they go back and retrace their steps to find out where and how they got lost. Poorer readers plunge ahead recklessly, failing to notice that they haven't a clue about what they're reading. Likewise, monitoring your own thought processes and deliberately altering them when they are not creative can help you to function more creatively.

You can take charge of a host of cognitive processes. You will see that you can deliberately pose your problems in the most abstract and general way to avoid getting hung up on the specific details of old solutions. Are you trying, for instance, to make a more durable vinyl record album, or are you really trying to find a way to store high-quality sounds over a long period of time?

You can also deliberately combine two different concepts and playfully explore alternate interpretations of their union. Sometimes, gloriously unpredictable novel ideas spring forth from combining even mundane words, such as tree and car. What after all is a tree car?

You can deliberately suspend your knowledge and mentally doodle with visual forms in interesting ways, and then later interpret their significance. In doing so you might discover a new invention or a new way of thinking about some problem.

You can deliberately try to forget the things that are blocking your path to a creative idea, by simply getting up and going somewhere else either physically or in your imagination. You can also try to apply analogies and test mental models. There are many other deliberate actions that you can take, but they all have something in common: they involve basic cognitive processes that one can learn to use more creatively.

STALKING THE CREATIVE MIND

The creative mind is an elusive quarry. How are we ever going to pin it down? How can we grasp it in our hands long enough to take its measure, to weigh, sort, catalogue, and classify it? Throughout this book we use a two-part approach.

We turn on the twin beams of laboratory findings and real-world examples to shed light on creativity. In the next three chapters we describe laboratory-based studies of creativity that help to elucidate some of its most basic principles. In the remainder of the book we survey how those principles operate in real-world settings, such as invention and product development, business, science fiction writing, science, and art.

The laboratory studies we describe have the advantage that they precisely manipulate and control all the details of a problem situation and measure the effect on creative performance. For instance, if we ask some people to work continuously on a problem and others to take short breaks at specified intervals, we can then compare their rates of success to determine which procedure is most beneficial.

However, these laboratory-based approaches have serious drawbacks. The most obvious one is that to achieve a modicum of control over the situation, it is often necessary to utilize somewhat artificial tasks. There is always the risk that we might eliminate the very essence of what we're after in our urge to control and measure it. The question naturally arises as to whether the results from laboratory studies have any applicability to the real world. Do we bag our quarry, only to find that we have captured an impostor?

Only in real-world settings can we determine if there are truly important ways to apply theoretical principles we derive in laboratory studies. One of the ways is to assess what creative people do, or say they do in mastering their real-world problems. In this way we can garner information about the various avenues people can travel to reach solutions to the most important problems.

However, examining creativity in these real-world settings has its own shortcomings. The first is that creative people may not be able to see into the workings of their own minds. Observing our own mental processes may not always provide reliable information.

A more serious shortcoming of the real-world approach is the "compared-to-what" problem. Even if creative people can correctly pinpoint the origins of their ideas, we have no way of knowing whether they might have crafted even more creative ideas employing some other procedure. Likewise, if a company successfully markets a product, or becomes more profitable by reorganizing its basic structure, we have no way of knowing how much better a product or more successful a reorganization might have occurred with some other approach.

Consider an analogy to the "compared-to-what" problem. One of the authors sometimes teaches developmental psychology and covers the topic of parental discipline. Invariably, at least one student will defend physical punishment by saying something like, "My father hit me a lot when I was growing up, and I turned out OK." The obvious question is, "OK compared to what?" How much more curious, inventive, motivated, or accomplished might the student have turned out if his father had not beaten him? We do not know, because we have no way to compare the student with who he might have been. Likewise, we have no way to know how much more creative a specific individual or company might have been if they had approached a problem differently.

Only by setting up direct comparisons can we determine the best approaches. This is where laboratory research comes in. By giving two groups of individuals the same problem and instructing them to adopt different approaches, we can be sure which approach is better for that particular type of problem.

The true nature of the creative mind should reveal itself in the two converging approaches. Neither laboratory studies nor real-world observations of creative behavior alone can capture all that is important about creativity. But, together they complement one another, and each helps to overcome the shortcomings of the other. If a laboratory study hints that some technique is useful, workers on the frontiers of innovation can try it to see if it stands the test of real-world application. If highly creative individuals report using a certain strategy, we can try to duplicate it in the laboratory to see if it is truly better than other approaches.

By analogy, one searcher might flush our quarry into the open so that the other can photograph it in all its exquisite and colorful detail. Come with us as we employ these two powerful allies in our quest to observe the creative mind.

NOTES

1. National Research Council, *Improving Engineering Design: Designing for Competitive Advantage* (Washington, DC: National Academy Press, 1991); M. E. Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990).
2. Kevin Desmond, *A Timetable of Inventions and Discoveries* (New York: M. Evans & Company, 1986).
3. George Basalla, *The Evolution of Technology* (London: Cambridge University Press, 1988), p. 2.
4. P. K. Engelmeier as quoted in G. S. Altshuller, *Creativity as an Exact Science: The Theory of the Solution of Inventive Problems*, trans. Anthony Williams (New York: Gordon & Breach Science Publishers, 1984), p. 5.
5. We use the word *problem* here very generally. It refers to any gap between what one desires and what currently exists. A composer who wants to write a symphony to make people feel the sense of

sorrow that results at the end of an ill-fated love affair has a problem in the exact same sense that a medical researcher who seeks a cure for cancer has a problem. Both need creative solutions to reach their goals.

6. Robert W. Weisberg, "Case Studies of Creative Thinking: Reproduction versus Restructuring in the Real World," in *The Creative Cognition Approach*, eds. Steven M. Smith, Thomas B. Ward, & Ronald A. Finke (Cambridge, MA: MIT Press, 1995), pp. 303–326.
7. Dean K. Simonton, *Greatness: Who Makes History and Why* (New York: Guilford, 1994).
8. Howard Gardner, *Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi* (New York: Basic Books, 1993).
9. Teresa Amabile, *The Social Psychology of Creativity* (Berlin: Springer-Verlag, 1983); Todd I. Lubart & Robert J. Sternberg, "An Investment Approach to Creativity" in *The Creative Cognition Approach*, eds. Steven M. Smith, Thomas B. Ward, & Ronald A. Finke (Cambridge, MA: MIT Press, 1995), pp. 303–326.
10. Ronald A. Finke, Thomas B. Ward, & Steven M. Smith, *Creative Cognition: Theory, Research, and Applications* (Cambridge, MA: MIT Press, 1992).
11. John H. White, *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978).
12. John H. B. Latrobe, *The Baltimore and Ohio Railroad: A Personal Recollection* (Baltimore: The Sun Book and Job Printing Establishment, 1868).

CONCEPTS AND CREATIVITY

New ideas, whether wondrously creative or merely unusual, are almost always constructed from the building blocks of prior knowledge. Truly creative ideas arise when we wisely preserve and extend what is worthwhile from existing knowledge, and reject only the ideas that constrain our thinking. The old knowledge roots our new ideas in what has worked in the past, and the new variations supply the novelty that is the hallmark of creativity. In creative endeavors, recognizing what to retain and what to reject can make the difference between success and failure.

Here we will explore the nature of old knowledge and how it can affect new ideas. Gaining an understanding of human knowledge in all its intricate complexity and stunning variety can help us to wield it more effectively as we approach our creative efforts.