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.
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11. John H. White, *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978).
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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.

YOUR VAST STOREHOUSE OF KNOWLEDGE

Reflect for a moment on how much you know about the world. You will see quickly that you hold the deed to a vast storehouse of knowledge, filled with an enormous number and variety of facts, ideas, thoughts, and beliefs.

Consider even just the small portion of that knowledge that you can bring to mind in the next few seconds. You know that you are reading a book. You may be seated on a chair or sofa, in an office or a living room. You may have a cat curled up next to you, or a dog at your feet. If you choose to, you can reflect on different styles of music, foods you like, the ideas of truth and justice, or our place in the solar system, galaxy, or universe.

We could go on forever, but suffice it to say that you know many things. Cognitive scientists would say that you have many concepts. You boast concepts about books, living rooms, cats, rap music, Italian restaurants, justice, the Earth, the universe, and so many other things that we could fill many books just with the list of those things, let alone explanations of what they are.

Concepts are essential for making sense of the world, and without them we would have no chance of being creative. Even the simple act of reading a story would be impossible without concepts. When you read the sentence, "Zelda loves pepperoni pizza," you can understand it only because you know what pepperoni pizza is; you hold a concept of "pepperoni pizza." You also possess a concept of love that is complex enough to tell you that Zelda's love of pizza is different from Romeo's love of Juliet, or a mother's love for her child. So when you comprehend what you read, hear, or see, when you reason, and when you create, you are drawing on your fund of concepts. But, what are concepts like, and how do they affect your ability to be creative?

SIMPLE CONCEPTS

Let's begin with some very simple concepts about tangible things, such as snakes and snails, and yes, even puppy dog tails. What are these concepts like?

When you visit a friend who has just gotten a pet boa constrictor you immediately recognize it as a snake without the slightest hint of having to work to identify the creature. If a waiter inadvertently brought you stuffed mushroom caps instead of the escargot appetizer you ordered you would notice right away. And if a four-legged, furry creature of medium size bounded up to you wagging its tail and barking, you would conclude at once that it was a dog.

Your concepts about snakes, snails, dogs, and any of the myriad of objects in the world you are familiar with give you the power to know one when you see one. Concepts, then, are like little packages of knowledge. When we open them up and look inside we see that they must contain, among other things, information about the properties that make an object what it is.

There are legitimate philosophical debates about whether any such properties are truly essential to the meaning of a concept—if that proverbial leopard really could change its spots, would it still be a leopard? But you know that when you stroll through a new park you readily classify those tall, leafy brown things that have trunks and branches as trees, even though you have never seen those particular trees before. Those properties are central to your concept of tree.

Rather than trusting their own intuitions about such things, however, researchers try to uncover the central properties of concepts by asking people to list characteristic attributes.[1,2] For example, if you were to jot down the properties that most guitars have in common, your list would probably consist of things like strings, tuning keys, a neck, a hole, frets, and so on. Most people

cite these attributes, and so we think of them as central to the concept of guitar.

How do these central properties impact on creativity? To a large extent, they tend to limit our imagination, and impose a structure on the new ideas that we develop. This phenomenon, called *structured imagination*, operates in real-world settings as well as in controlled laboratory situations.[3] Before reading about the research findings, however, try the following task for yourself: Imagine a planet somewhere else in the universe that is very different from Earth. Now imagine an animal that might live on that planet. What does your creature look like and how does it behave? How would you draw this alien being?

If you are like most college students tested in this type of experiment, you gave your creature eyes, located in a distinct head, and either two or four legs (see Figure 2.1). You most likely also made it symmetric. In other words, you endowed it with the central properties of Earth animals.

Even though there is no reason why creatures living on another planet would have to look this way, people seem to have trouble thinking of other possibilities. What they know about Earth animals colors their imagination about extraterrestrials.

This structuring comes about because when we must develop new ideas, we recall old ideas and use them as a starting point. Since central properties are such integral parts of our concepts, they work like implicit assumptions. They are part of our unconscious baggage. We do not even consciously question whether they are essential to the old concept, much less the new idea we are trying to formulate. We just import them directly into the territory of the new concept without declaring them at customs, or even stopping to have our old baggage inspected.

It is not surprising, then, to find the central properties of old concepts cropping up in otherwise novel creations. The very same properties that serve us so well in deciding whether an object is a dog, a cockroach, a computer, or something else, encroach on our ability to innovate.

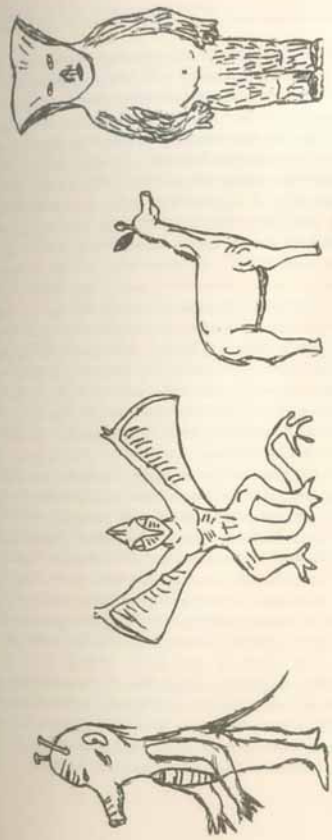

FIGURE 2.1. Drawings of imaginary creatures produced by college students (adapted from Ward, 1994).

A cynical reader might observe that the college students we test are not going to come up with imaginative extraterrestrials; they're a pretty dull lot. A debatable point, no doubt. What is striking, though, is that this structuring phenomenon pervades so many creative activities, even among highly imaginative individuals. For instance, *Barlowe's Guide to Extraterrestrials* contains a marvelous collection of extremely imaginative creatures from science fiction.[4] If you study those examples, however, you will notice that they exhibit symmetry, legs, and eyes. In fact, three fourths of the creatures in *Barlowe's Guide* are equipped with these properties.[4] The same is true for creatures in the wonderfully creative "Star Wars" and "Star Trek" series.

Science fiction writers occasionally bring to life creatures that challenge our most basic assumptions about animals, such as Fred Hoyle's "Black Cloud," a huge intelligent cloud of hydrogen, or Piers Anthony's "Polarian," a being with a teardrop shape and no standard appendages or senses. However, these are clearly the exceptions, and are all the more remarkable for their rarity. Our imagination is ordinarily much more structured than we might think.

Earlier we saw how this same tendency of old properties to infiltrate new concepts gave rise to train cars with the unsafe features of running boards and external seating for conductors.[5] Those features had been central properties of stagecoaches. When designers fashioned the first train cars, they patterned them directly on stagecoaches, with which they were intimately familiar. Consequently, railway cars mimicked that prior mode of transportation, despite posing some dangers for the people who operated the trains, not the least of which was falling off.

Generally, the central properties of old concepts can insinuate themselves into new ideas and limit innovation whether in science fiction, invention, product development, business organizations, art, or science. In all of these pursuits, old knowledge influences even the most highly imaginative ideas.

Deploying old knowledge in the service of new ideas certainly does have benefits. It can bring forth expedient solutions, set the stage for further developments, and prevent us from becoming hopelessly mired in frivolous pursuits. When Kekulé had his insight about the benzene ring, he didn't first have to invent the concept that carbon atoms would join together. Rather, he had to specify the particular way in which they united with one another. Soft drink makers of today concoct an astonishing range of delicious and refreshing carbonated beverages. But they don't have to first dream up the notion of infusing liquids with carbon dioxide. Joseph Priestley did that for them in 1767.

However, as in the case of train travel, which represented a distinct break with past modes of transportation, or in the more modern case of corporations needing to adapt to changing market conditions, there are times when we want to shun the influence of certain central properties. There are times when it might be better to forget about what has come before and start over.

Through the tools of cognitive psychology, we can unveil the central properties of existing concepts. Then, armed with that information, we can predict what new concepts will look like. We can pinpoint the exact bits of old knowledge that are most likely to hang us up or hold us back in our quest to be more innovative. As we have seen, previous studies revealed that people consider eyes[6] and legs[2] to be central properties of animals, and so we could readily predict that most of our college students, as well as most science fiction writers, would insert those properties into their imaginary creatures.

Knowing about central properties also can help us predict what people will change when they generate new ideas. The central properties serve as the basic themes on which we can play new variations, or the skeletons that underlie and give form to the flesh of new ideas. Oftentimes people modify and build on central properties. Thus, the students imagined creatures that had the central property of eyes, but experimented with their

shape, number, size, and locations. Some drew many eyes at the ends of long tentacles, others a single eye placed squarely in the center of the creature.

Most importantly, we can also open our minds and become aware of these central properties that we hold so tightly yet tacitly. By dragging the central properties of a concept out into the open, we can assess their worth, take their measure, and decide whether to accept, reject, or transform them as we craft new ideas. We can stop them at a customs checkpoint on the border of the new concept, and confiscate them if they appear to be contraband. This can help us to contrive more innovative concepts, whether in business, art, science, or day-to-day living.

Central properties also provide us a means by which to gauge the originality of a new idea. We can tally how many key features of the old concept are preserved and how many are excluded. We can also draw a distinction between modifying an attribute and rejecting it entirely. Rejecting a central property would, in most cases, count as a more dramatic change.[7] If you endowed your alien with an organ that senses variations in gravity, but gave it no traditional sense organs, we would judge it to be more original than if you simply placed normal eyes and ears in unusual locations. If a soft drink maker infused water with some other gas, say helium or oxygen, we might judge the new concoction more original than if they simply added new flavors to the same old carbonated water.

ATTRIBUTES THAT CO-OCCUR

Suppose that you just happen to catch a two-wheeled vehicle out of the corner of your eye. When you turn to look more closely you are surprised to see that it has a steering wheel, just as you would be if a four-wheeled vehicle sported a set of handlebars. Bicycles and motorcycles are "supposed to" have handlebars, and cars, trucks, and vans are supposed to have steering wheels. We just naturally expect some features to go together.

In fact, if you consider the central properties of many of your own concepts, you will notice that some attributes seem inextricably linked with others. A lifetime of experiences has taught you well that where you find certain features you are bound to find others. Where there's smoke there's fire, so to speak. Our observations of nature, for instance, tell us that wings belong more with feathers than with fur, and gills more with scales than with either feathers or fur.

How might this aspect of our concepts influence creativity? If people carry over one central property to a new idea, they might also throw in other properties that just happen to be correlated with it, whether or not it makes sense to do so.

Recent experimental research provides direct evidence for exactly this possibility.[8] When college students were told that the imaginary creature was feathered, they designed animals having wings and beaks, and when they were told it had scales, they incorporated gills. When told it was furry, they avoided wings, beaks, and gills entirely (see Figure 2.2 for some examples). Extraterrestrials need not contain these correlated properties, but our knowledge of their co-occurrence in Earth animals is so powerful that people inject them into new ideas anyway.

Since cognitive psychology can unveil the subtle correlations between known properties, it can put us on the lookout for their impact on our creative efforts. By shining the light of conscious awareness on those connections we also can learn to avoid them in our new ideas if we deem it desirable. In designing a new two-wheeler, for instance, we might be able to consider whether to steer it with a wheel, a joystick, a knob, or some other device rather than being held tightly in the grip of handlebars.

TYPICALITY

Which is the more typical breed of dog, a collie or a basenji? What are more typical pizza ingredients, pepperoni and mush-

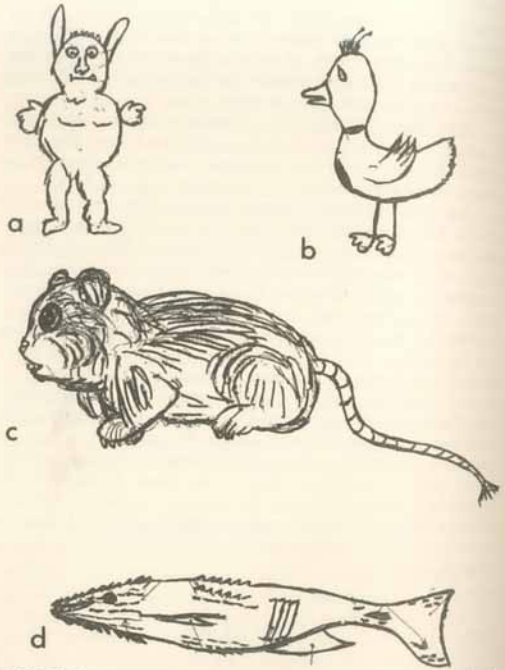

FIGURE 2.2. Imaginary creatures produced by college students given no special instructions (a), or told the creature was feathered (b), furry (c), or scaled (d) (from Ward, 1994).

rooms or eggplant and pineapple? We answer these questions easily, and most often agree with other people about the best answers.

Some things just seem to be better representatives of a concept than others.[8,9] Generally, the more central properties a thing has, the more representative it is of its category or concept. How might this impact on our efforts to be creative?

Research shows that we call up typical instances of a concept faster than less typical ones.[9] To see this for yourself, quickly name the first five birds you can think of. Your list is likely to be populated with very typical birds, such as robins, bluejays, and sparrows, and less likely to contain unusual birds, such as pelicans, ostriches, and penguins.

Because more typical instances of a concept spring to mind first, we naturally tend to seize on them as starting points in developing new ideas.[3,5] And because the most typical members of a concept are the ones that have all of its central properties, this can reduce innovation even further. For instance, robins fly, lay eggs, and build their nests in trees, but penguins do not. If you base a novel alien on the more typical robin, it will resemble a stereotyped bird more than if you base it on a penguin.

Thus, by opening and expanding our minds to explore the outer limits and dazzling variety of our concepts we can go beyond the typical and concoct novel ideas that are wonderfully unusual. But this might take a bit of effort and patience. We might have to inhibit a strong desire to jump on the first idea that comes to mind, and we might have to forcibly dredge up less typical examples of a concept. The reward of more innovative ideas is worth the price of the additional effort.

Science fiction writers wield this technique to great effect. Most of them recognize that there exist more wild varieties of life on Earth than most people could dream up for other planets. And they gather a rich harvest of ideas from the seeds of these most extraordinary instances. By embracing the knowledge we already have rather than rejecting it, we can develop new and innovative ideas. And by drawing on less typical concepts we have more to work with to enhance the originality of new ideas.

FLEXIBILITY

So far we have focused mostly on how our stock concepts can limit creativity. But let's see how exploiting concepts more effectively can boost our creativity.

First, think about the concepts you actually bring to mind. Are they rigid structures that you simply retrieve when you need them? Or do you actively construct them from bits and pieces of information in your vast storehouse of knowledge?

By the first view, your concepts are like books in a library. When you need one, you simply pick it up from the right shelf. By the second view, you construct a different "book" each time you need it from a library of separate pages. The first system would be more efficient, but the second would be more flexible, and would foster more creativity.

For many years, cognitive psychologists accepted the "fixed structure" view without question. But recently the "active construction" view has become more popular. To see why, read the two following passages.

> As Mary reached the third floor landing she could hear the familiar clicking of nails on the linoleum floor of her tiny apartment. She could picture Muffy scurrying to reach the door to greet her. As she unlocked the door, she let out a sigh and thought, "It's nice to be home with my dog."

> As John set his shotgun in the gun rack and stepped out of his truck he could hear the familiar scratching of nails on the hardwood floor of his cabin. He could picture Gus bounding toward the door to greet him. As he unlocked the door, he let out a sigh and thought, "It's nice to be home with my dog."

Did you picture the same dog for each of these passages? Probably not. You would probably be surprised if Muffy turned out to be a Saint Bernard and Gus turned out to be a toy poodle.

Why? Because the events in each passage led you to construct very different images of dogs. In other words, what you retrieve from your memory as a "typical" dog is not fixed, it is flexible.

The way you think about any concept may be slightly different every time you think about it. This is partly related to the fact that the exact concept you bring to mind depends on your immediate situation, and no two situations, no matter how similar, are ever identical. Even if you eat the same type of hamburger, at the same fast-food restaurant, with the same friends every night, you will not have the exact same experience every night or hold the same conversation, word for word. The events leading up to the meal will change from day to day, and they will influence your experience of the meal and the nature of the ideas you conjure up. Perhaps your favorite team just moved within a game of first place, or your preferred candidate just moved down in the polls, or your sink was clogged that morning, or you were slapped with a parking ticket or summoned to jury duty.

These recent experiences impact on exactly what we bring to mind. If you've just seen the popular movie "Beethoven," about a lovable Saint Bernard, the image you get from the sentence, "John petted the dog," will be different than if you have just seen "101 Dalmatians." Similarly, your immediate thoughts about pollsters, pundits, and politicians will waver with the standing of your candidate, and your concepts of police officers and the justice system will reflect the reasons you are headed to court.

Research verifies that the exact concepts we construct change from one time to the next. In one experiment, Francis Bellezza of Ohio University had people provide definitions for a set of words, and then return a week later to define the same words a second time.[10] He found that people's definitions changed greatly from one week to the next. In other words they constructed their concepts differently on the two occasions.

You may have a few typical versions of most concepts that you call on for certain standard situations, but it is unreasonable to think that you have an infinite supply of fixed, prestored

structures ready to go in anticipation of every possible situation in which you will need to dredge up every concept you know. It is more reasonable to believe that you have the ability to construct exactly the concept you need when you need it.

This is good news for creativity. Since it is very natural for us to construct familiar concepts, we can seize on the same basic process to construct novel ones. What we need to do is take control of the process and deliberately use it to develop more innovative concepts.

So now let us design a novel alien, using the concept of "dog" as a starting point, but not a whole standard, prestored example of a dog, rather a construction of a dog from its central properties. Think about the properties that most dogs have in common and combine them in some pleasing way to get a completely novel animal. Perhaps when we consider that dogs have four legs, for example, we can deliberately ask whether our novel creature might have some other number of legs, such as three or five. Similarly, we might systematically vary other central attributes of known dogs. Do they really need to be a certain size, or have two ears, and one tail?

What we see is that by working with the central properties of our concepts we can make our implicit assumptions become explicit. We can bring them to light and then either retain, reject, or modify them.

This same approach can be used to develop creative ideas for inventions, as in the procedure called morphological forced connections.[11] In that procedure, for example, one might take an existing invention, mentally chop it into its basic attributes, and then consider all the possible variations on those attributes. By playing with the different variations, one might come up with an interesting idea for a new invention. For instance, we might develop a new eating implement by taking the familiar fork and varying the length and shape of its handle, the material from which it is made, the number, size, and separation of its tines, and so on. We might assemble a tasty new sandwich by experimenting with different combinations of all the types of breads,

meats, cheeses, vegetables, and condiments we can think of. Only our taste buds would tell us if pastrami and provolone on six-grain bread with onions and French dressing would produce a delightful new taste sensation.

GETTING DOWN TO BASICS

One other aspect of our concepts that limits innovation is that we seem to think of our concepts in very concrete ways. Consider the picture in Figure 2.3. What is it? Most likely you said it was a cat. You could have called it a Siamese, a mammal, an animal, a living thing, a tangible thing, a furry thing, a thing, or any of an infinite number of other possibilities. Yet your first reaction was to think of it as a cat.

FIGURE 2.3. Siamese cat.

Eleanor Rosch, a prominent cognitive psychologist at the University of California at Berkeley, pointed out that most people classify objects in the same way, as cats, dogs, birds, fish, and so on.[8] She called this the "basic level" of categorization. This very powerful tendency impels us to think of most things on a very concrete level. We seem to be drawn to the wealth of directly observable features such as legs, wings, and fins that help us to distinguish between objects at this level of abstraction. It is simply easier for us to do so.

The consequence for creativity is that, when we try to develop new ideas, we also tend to rely on the basic level, and to get stuck on concrete observable properties. The majority of people who generate imaginary creatures in laboratory experiments claim that they base their creatures on specific Earth animals, such as dogs and elephants.[3] The people who drafted these "basic level" animals into service were the ones whose aliens were the most similar to Earth creatures.

ABSTRACTION

One essential aspect of our concepts that we can capitalize on is their potential flexibility. Even though we tend to think on a basic level, we are not bound to that level. For instance, you can readily think of the cat in Figure 2.3 as an animal, a furry thing, a member of the class of things that weigh between 5 and 15 pounds, and so on. A friend, who shall go nameless, thinks of his dog as a furry thing, and slides her around on his wooden floors to pick up dust bunnies.

One way to exploit the flexibility of concepts is to recast them in more abstract terms. When we want to design a new alien creature, we do not have to base our ideas on specific Earth animals, such as dogs and elephants. Instead, we can reach beyond the limits of concrete images and can cobble together a more general concept of animals and their fundamental properties.

What are animals like in their most abstract sense? They must extract information from the environment, obtain an energy source to carry on biological processes, protect themselves from hazards, and survive long enough to reproduce. What happens if we construct a novel creature using this abstract representation of the concept of "animal"?

Suppose that, instead of basing an imagined animal on your pet dog, you considered only the more abstract idea that living things need some way to take in information about the world around them. Posing the problem this way might evoke all sorts of innovative ideas, including organs to sense magnetic fields, wind speed, gravity, heat, humidity, and so forth. The more abstract approach leaves more room for the imagination, and is likely to inspire us to call up ingenious variations on the senses.

Our studies confirm that abstraction leads to more innovation.[3] The college students who developed more innovative creatures stated that they had considered abstract ideas such as what the planet was like and what the animal would need to survive there. Examples of more unusual creatures are shown in Figure 2.4.

The students who thought more abstractly went beyond the familiar physical characteristics of Earth animals to consider the bigger picture. By establishing the rough outlines of the planet first they were then able to fill in exotic details to tailor their aliens to its conditions. By pondering the essence of what it means to be an animal, they escaped the bonds that might have tied them to any one specific animal.

Thus, old information can help us to develop new ideas, particularly if we pull it up in an abstract form. Forming abstract thoughts is not that difficult because of the way we naturally organize information in our memories. It is relatively easy to think of your pet dog in more abstract ways, as a mammal, an animal, or a living thing. You have already wired the connections between those levels of abstraction through a lifetime of experience with living things. For the same reason it is also easy to think of eyes and ears more abstractly—as devices for getting information from the environment.

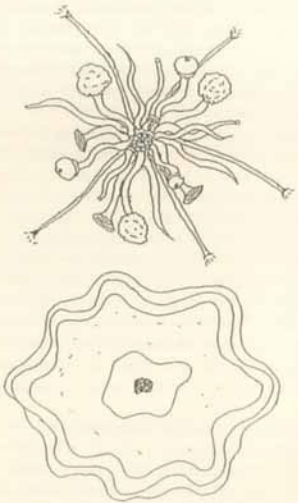

FIGURE 2.4. Examples of more unusual imaginary creatures produced by college students.

It seems that bringing to mind *specific* old ideas, such as dogs and stagecoaches, locks us into the details of those objects, making it difficult to think of highly original new ideas. Concentrating instead on general, abstract information in one's mind leaves room for more pointed and original innovation.

Abstraction also aids in the task of making our assumptions explicit. To get to the abstract levels, we have to consider our most fundamental assumptions. In the process we learn more about our own concepts, our most deep-seated beliefs about what's important in the world. We also set the stage for extending and expanding on our concepts.

Abstraction also helps crystallize what we are trying to accomplish. Consider the store owner, for example, who viewed himself as selling records and tapes, a very specific, narrow idea. The recent trend toward putting music and video on CDs could have threatened to put him out of business. On the other hand, if he viewed himself as a provider of home entertainment, a more abstract characterization, a switch in the medium would not have been threatening, and might even have opened up new opportunities.

Abstraction is vital to creativity. It allows people to dodge the inhibiting properties of more specific concepts. We will see that abstraction is a very general principle that elicits greater innovation in problem solving, product development, and science fiction writing.

AD HOC OR GOAL-DERIVED CATEGORIES

Another aspect of concepts that can expand our creative potential is that we readily form new ones as we need them for new situations. Lawrence Barsalou, a noted cognitive psychologist at the University of Chicago, refers to these concepts we construct on the spot as ad hoc or goal-derived categories.[9] To get a sense of one such concept, consider the following items: children, important documents, pets, money, and clothes. At first they do not seem to form much of a concept, but when you hear that they are things to take from your home in the event of a fire, the concept emerges clearly out of the mist. You also can summon up other items, such as photographs and jewelry.

Notice also that this new, "ad hoc concept" includes items that we usually place in different groups. Children and pets, for instance, might be members of the group "living things," whereas

money and documents might exemplify the group "nonliving" or "paper artifacts." In conjuring up ad hoc concepts, we have to be flexible in reorganizing our existing concepts.

Barsalou's research reveals that people easily contrive and comprehend ad hoc concepts. This shows that a basic process of creative thought is readily available to all of us.

This ability to reorganize our concepts may spark creative solutions, particularly in many day-to-day situations that call for creative flexibility. Let's return, for instance, to Lola and her fuel line. She had to forge an ad hoc category of "things to plug a car's fuel line." Her choice of a potato required a clever reorganization of her concepts. We constantly face similar tasks, as when we have to think of things to stand on to change a light bulb, objects to hold papers in place on windy days, and activities to entertain children on long car trips.

ESSENTIAL PROPERTIES

One aspect of concepts that restricts our potential for novelty is that many may possess essential properties. A concept may have certain features that are of such supreme importance that changing those properties alters the concept completely.

Consider a task that Frank Keil, a noted cognitive developmentalist at Cornell University, gave to his subjects.[12] Suppose some scientists got a raccoon, painted it black, dyed a white stripe down the middle of its back, and sewed in a scent gland that would release a foul odor. Would this creature still be a raccoon, or would it now be a skunk? If you were like most adults in Keil's study, you'd say that it was still a raccoon. Why? Because you believe that there is some essence of raccoon that remains. If the scientists could have changed that essence, perhaps by manipulating the genetic structure of the raccoon, they might have changed it to something else.

Similarly, if we don't endow our imaginary aliens with certain properties, other people might not think of them as

animals at all. Thus, there are constraints on just how unusual ideas can be and still remain workable.

Let's take a slightly different example that shows how quickly people change their minds if we change the essence of an object. Suppose these same scientists took a coffeepot, sawed off the handle and spout, sealed the top, cut an opening in the side, and filled it with bird food. Would the object be a coffeepot or a bird feeder? Again, like most adults, you probably would say it was now a bird feeder. Why? Because the changes altered the basic function of the object, and function is the essence of an artifact. Any change in the function will change the concept of an artifact.

Together these results tell us that there are some limits on flexibility. We can bend and twist our concepts in many ways, but if we cross the line and change their essences we risk breaking them. Even highly creative people are unlikely to think about changing the essence of a concept in developing a new idea, and if they do alter it, we may not even recognize their creation for what it is supposed to be.

CONCEPTUAL COMBINATION

As we have seen, one way to generate more creative ideas is to use very abstract knowledge. Another way is to amalgamate two separate concepts into a single new idea. In fact, we merge ideas constantly as we try to make sense of the world around us. Prior to the development of microcomputers, for instance, you probably had never heard of a "computer table," but you had no difficulty making the leap to combine your concepts of "computer" and "table" to understand what computer tables were. Nor did you stumble when you first encountered other expressions, such as "religious right," "cautious optimism," "shuttle pilot," or "head banger."

Even young children expand their vocabularies by coupling together separate words to express a new thought. Deana Ward

was only two years old when she reported that she had a "soggy nose." She certainly knew what soggy diapers were, but nobody had ever told her that, when you had a cold, noses got soggy too. She came up with this delightful novel expression on her own. Connor Ward entered the fray at about the same age with "alligator car" to refer to a favorite green toy car of his. It is not at all unusual for children of these ages to push the limits of their language this way.

We call this melding of two ideas *conceptual combination*. What makes this seemingly simple ability so exciting is that it can lead us to generate novel and surprisingly creative possibilities.

As an analogy to the power of conceptual combination, think for a moment about hydrogen and oxygen. Put them together in the right combination and you have something entirely different from either of the gases alone, namely water. From knowing about either gas alone, you could not have predicted that ice would float, a hot shower would feel so relaxing, or a cool drink would be so refreshing. Simple concepts are like these simple gases. Alone, they have known and obvious properties. Put them together, and seemingly magical transformations can occur. But, it is not magic; it is simply a creative aspect of ordinary cognition.

Research verifies the seemingly obvious point that from a combination can emerge new properties that were not evident in either of the original concepts. For example, Gregory Murphy of the University of Illinois had people rate how true certain properties were of individual concepts and their combinations.[13] One set of concepts consisted of the individual words *empty* and *store* and their combination, *empty store*. Consider the property "losing money." Like subjects in Murphy's study, you probably recognize that losing money is typical of empty stores, but not of stores in general or of things that are empty. Something changes when we draw the concepts together.

One of our favorite examples of conceptual combination is a "computer dog." Ponder for a moment what that might be. You may have thought about one or more of the following: a virus

protection program that barks when it detects an intruder, a simulated or virtual dog, a hacker or computer nerd, a robotic dog, or a hot dog prepared in a computer-controlled device. The point is that many new possibilities emerge that might never have occurred to you had you thought only of dogs and computers *separately*. Perhaps you've thought of a completely different, and more interesting possibility.

A particularly stimulating interpretation is that a computer dog is a peripheral device, similar to a mouse, for interacting with a computer. This last idea highlights the fact that conceptual combination can be a source of ideas for new inventions. It also underscores the importance of the exploration phase of the Geneplore theory we introduced in the first chapter. Like most new concepts, our "computer dog" is just a vague idea until we bring it to life through further exploration.

We asked students to envision what a computer dog would be like if it were a variant on a mouse. They produced several innovative ideas, one of which is shown in Figure 2.5. This idea evolved because one student suggested that the device should

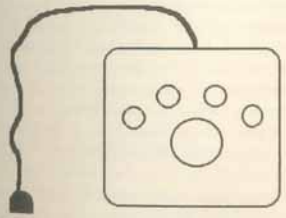

FIGURE 2.5. Sketch of computer input device developed by college students who explored the combination "computer dog."

resemble a dog's footprint. A second followed with the idea that the individual pads would be buttons with different functions, and a third proposed that the central pad could be a rolling trackball. The idea naturally leads to more playful explorations. What are the functions of the different buttons? What can you do with four buttons that you cannot do with the usual two buttons of a mouse? What is the trackball for? How do the functions of the buttons and ball interact? The point is that a potentially useful and clever invention could originate from these simple efforts.

Conceptual combination is not limited to putting together simple object concepts, such as "computer" and "dog." Consider, for example, the hilarity, the wisdom, and the inspiration that blossom forth when people pool their talents. What would Laurel have been without Hardy, Abbott without Costello, or Moe without Larry and Curly? Would Sherlock Holmes have been the same without Watson? Would Crick have found the structure of DNA with a different Watson? And wouldn't the world be a poorer place if not for the pairings of Rogers and Hammerstein and Gilbert and Sullivan? The humor, suspense, discovery, and beauty that emerge from these sorts of alliances speak volumes about the power of combinations.

Conceptual combination can be applied to help develop new products, literature, art, and scientific concepts. Combos snacks that roll cheddar cheese into an outer shell of pretzel are one such food product, and the works of pop artists, such as Andy Warhol, that combine art with commonplace objects from popular culture give us a hint of the possibilities in the art world.

Those who give advice about how to be creative have often mentioned the importance of combinations,[11] but we are only now beginning to find out why they work. We also are finding out why some types of combinations lead to more creative possibilities than others. We no longer have to rely on a "brute force" procedure of randomly testing a huge number of combinations.

One factor that matters is how close or compatible the two concepts are. Generally, the further apart the concepts are, the more they allow for original ideas to emerge.[14] In other words, combining two similar animals, say a "squirrel possum," is less provocative than combining a tool and an animal, say a "hatchet gorilla."

More original ideas may also spring forth when we combine opposites.[15] This style of combination is called Janusian thinking in reference to Janus, the Roman deity who was depicted as having two faces on opposites sides of his head. Intriguingly, Janus was the god of doors and gates, which points to a tantalizing symbolic link to creativity. By invoking this mode of thinking we may open doors to a world of new possibilities.

Shakespeare evoked powerful and poignant emotions with his enduring literary notion that "parting is such sweet sorrow." Many a would-be comic has earned at least a mild chuckle by noting that "military intelligence" is an oxymoron, combining two seemingly contradictory concepts. And Newt Gingrich recently blasted the Americorps program as being "coerced volunteerism." The program is designed to help young people attend college when they have given of themselves to help our country. But however you feel about its merits, you can see that Newt's nugget combines conflicting concepts into a catchy phrase that is bound to swing some votes. It is clear that there is something inherently enticing about combinations of opposites whether they lead to actual inventions, vivid literary images, or just snappy expressions.

METAPHOR

Metaphors are a kind of conceptual combination that can be used to express ideas creatively, and that can lead to creative change in the mind of the person who hears them. Stating that football is the demolition derby of athletics cleverly expresses

the energy and violence inherent in football. Saying that golf is the antique car show of athletics captures the relative tranquility of that sport. In either case, the concepts of athletics and automobiles are combined, leading us to view each one a little differently.

Research documents that new properties and concepts can emerge from metaphors.[16,17] The properties that pop into your mind for golf and antique car shows separately will differ from those that strike you when you combine them into a metaphor. Similarly, when you comprehend a metaphor, such as "my job is a jail," you may construct a completely new, ad hoc category, such as the set of items that are unpleasant and confining. You can then probe that concept more deeply and develop new examples, such as a large mortgage or an unsatisfying relationship.

Metaphors can help to overcome some of the constraints of our staid concepts. By allowing us to view objects in a new way, with new properties, and as members of new concepts, we can free ourselves of the bonds of the past and move off in entirely new directions.

SCHEMAS

Our knowledge is also arranged into complex structures called schemas. Schemas play a crucial role in the organization of our memories by telling us how our simpler concepts relate to one another. You probably have a "living room" schema comprised of many simpler concepts, such as a sofa, chairs, a coffee table, lamps, and possibly a television, VCR, and stereo equipment. Your schema provides a map of how those items are organized. They are not just piled together in the middle of the room. The coffee table may rest in front of the sofa which faces the television, and so forth.

You probably also have a schema that depicts a typical visit to a restaurant: a hostess greets you, guides you to a table, and

hands you a menu. Following that you may peruse the menu, order a dish, receive and eat your food, obtain a check, pay, and leave.

Schemas allow us to behave efficiently. We know what to expect and how to behave when we walk into a living room or eat at a restaurant. We have difficulties only when something violates our expectations, and those problems disclose the power of our schemas. To take just one example, if you were to wander into a restaurant in Germany and wait by the door for a hostess to seat you, you would wait a long time. It is customary in Germany for patrons simply to seat themselves at an empty table. Further, in many restaurants, if no tables are empty, the norm is to approach a table that is already occupied and ask if an empty chair at that table is "free." If the reply is "yes," the custom is to sit down in that chair at the table. Try doing this in a restaurant in the United States.

The problem with schemas is the same as that regarding simpler concepts. When our goal is to produce something new, our schemas can constrain us as much as they can help us. Roger Schank, a well-known expert on schemas at Northwestern University, described the pitfalls of schema-based thinking.[18] Because they can be applied nearly automatically, they allow us to behave very efficiently. But, for the very same reason, schemas allow us to stick mindlessly with old ways of interpreting situations and solving problems.

As with simpler concepts, a way to overcome the influence of schemas is to recognize their central properties. By making explicit the underlying assumptions that are built into a schema, we put ourselves in a position to challenge and change it.

ANALOGIES

One of the great resources for artistic, technological, and scientific advancement is *analogy*, taking concepts from one area and extending them to another. A well-known example, mentioned

previously, is Lord Rutherford's adoption of the solar system as a possible model for the structure of the hydrogen atom. Although subsequent work in physics demonstrated that the model was not quite right, it still provided a powerful new way to think about atoms. And it stimulated an onslaught of invaluable research and discovery in chemistry and physics. A more recent example of the creative use of analogy from the world of product development is the Reebok Pump. The idea for the design was borrowed from a relatively recent medical marvel, the inflatable splint.[19]

We all employ analogies in understanding the world, but we can also fashion them deliberately to our creative advantage. The *synectics* approach proposed by the noted creativity expert William Gordon makes use of analogies for creative problem solving.[20] Gordon claims that you should exploit many varieties of analogies in creative thinking, such as personal analogies in which you envision yourself as one of the parts of the problem, and direct analogies in which you borrow examples from nature to better understand the problem. For instance, in trying to devise a better mousetrap, you might investigate how different kinds of spiders catch their prey.

The synectics approach is a relatively old one, and we have learned much about what makes a good analogy since it was first introduced. One of the difficulties in using an analogy is knowing which features you should hold onto and which you should discard. When we say that an atom is like the solar system, surely we are not claiming that its nucleus is yellow and has a surface temperature of 5800 degrees Kelvin. What we really mean is that there are smaller entities orbiting around a more massive central entity and that some force prevents them from flying away. But how do you know in advance what are likely to be the most vital similarities?

New research in cognitive psychology tells us that the attributes to keep are those that share similar "higher-order relations," which specify how separate objects are connected.[21] In this case, a higher-order relation might be "revolves around,"

and thus you might retain the idea that the smaller bodies revolve around the larger ones. The point is, in using analogies to understand something new, do not be misled by pure surface similarities and differences. It is the deeper similarities that are more important. As with the process of abstraction, analogies can help us to narrow down the set of properties that are worth considering.

Later, we will see how creative individuals use analogies in invention, writing, art, and science. Again, knowledge is good because it allows us to map useful properties from one domain to another, particularly if we focus on the higher-order relations that link separate objects.

MENTAL MODELS

Mental models are the most complex cognitive structures we will consider. Just as schemas depict the links among several simple concepts, mental models can consist of several schemas working together.

We actively construct mental models to comprehend complex phenomena, and we use our general knowledge about the workings of the world to do so. We might want to understand the nature of the digestive process in humans, how a clutch or brake system operates, or why the sun, moon, and stars appear and disappear in a consistent sequence. The mental pictures we form of the component parts of these systems and how those parts interact are called mental models.

Let's consider the day/night cycle. As adults in a modern culture, we know the scientific explanation: the Earth is a sphere that rotates on its axis. We also know that the sun and moon are spheres, and that the Earth revolves around the sun and the moon around the Earth. But consider what a young child's model of the system might be like, or that of an adult without the benefit of modern scientific knowledge.

Many first-graders believe that the Earth is flat and motionless, and that the sun disappears at night behind mountains or clouds.[22] Because a flat Earth would not have an "other" side, these children do not think of the sun as being on the other side of the Earth at night. The children's models are similar to those of the earliest astronomers who thought the Earth was flat and motionless, and that the sun hid behind hills or mountains, or went under the Earth at night.

How do children develop more accurate mental models? How do astronomers or other scientists accomplish this? For children, it is a question of how they learn what adults consider to be the right answer, but for scientists, it is a question of how they make the creative leap from an older to a newer way of seeing the world. One way to change a model is by changing, eliminating, or suspending the presuppositions that we use in constructing it. Once again, we see that deliberately examining our most basic assumptions is one of the key paths to change and innovation.

For example, the correct model of the day/night cycle involves a rotating Earth, but it does not make sense to think of a flat Earth as rotating, at least not in a way that plausibly could explain the disappearance of the sun at night. This is especially true if the flat surface is supported by ground going downward indefinitely. So, if we hold the basic assumption that the Earth is flat, it is difficult to construct the appropriate mental model of the day/night cycle.

And a flat, supported Earth seems reasonable because unsupported objects (and people) fall downward. So, intuitively, the Earth needs to have a flat living surface because objects would fall off an underside, and it needs to be supported rather than floating freely in space.

Once we make explicit our flat-Earth theory, we can challenge or reject it in favor of some other shape, such as a sphere. By doing so we then can envision the sun being on the other side of this sphere at night, and ultimately we can envision the change in the sun's relative location as being the result of the rotation of the sphere on its own axis.

This example of discovering a better model for the day/night cycle shows again how creative advances develop from making our assumptions explicit so we can challenge them. Clearly, we can only do this if we are able to identify the very assumptions that should be challenged.

Mental models can also have a profound effect on our ability to develop creative innovations, particularly for complex systems. When we generate and explore them, they allow us to set up hypothetical situations, make predictions about outcomes, and mentally "run" the model to test those predictions. A nephew of one of the authors had a less than complete mental model of digestive processes and wondered why liquids, such as milk, had certain colors entering the body but exited a different color. He came up with the hypothesis that the length of time the liquid was in the body might determine the color change. In his model, more time equaled more change. Being a budding young scientist, he developed the appropriate experiment to test his model: drinking milk while standing in the bathroom. Unfortunately this did not advance the cause of science greatly, but it does show how even young children can use mental models to come up with interesting and creative ideas for experiments.

Mental models can even influence the way we live our lives, right down to our simplest everyday customs. Consider, for instance, what we say when someone sneezes. A typical response is "God bless you," or "Gesundheit," which means "health" in German. Why do we express concern for the person's spiritual or physical health? According to Charles Panati, author of *Extraordinary Origins of Everyday Things*, this custom originated with the idea that the soul or essence resided in the head, and with the related concern that a sneeze might inadvertently expel it.[23] Ancient peoples also had observed that sneezing preceded death from certain diseases, which led them to pray for those who sneezed. Interestingly, around the third century B.C., Romans thought sneezes might expel the "sinister spirits of later illnesses,"[24] which led to the custom of congratulating the sneezer.

The contrast between the customs of praying for and congratulating the one who sneezes is instructive. The customs are

based on contrasting views of sneezes being harmful versus helpful, which in turn are based on contrasting naive theories about whether a sneeze is likely to expel one's soul or some harmful spirit. The point is that we use our theories about the workings of the world to construct mental models which, in turn, influence many aspects of our lives, even down to such simple conventions as what to say after someone sneezes.

Most of us no longer believe that people who sneeze risk expelling their souls, but the custom remains. This is an illuminating example of intransigence in changing our patterns even when the original reason for behaving a certain way is lost. The superficial action remains, but the deeper or more abstract reasons are obscured. Changing our customs requires bringing our assumptions into the open so that they may be assessed, altered, or possibly rejected. A recent example is the push to adopt year-round schooling, rather than retaining extended summer vacations which are a throwback to an earlier era in which children were needed to help out on the family farm.

We have examined many varieties of knowledge ranging from simple concepts to elaborate mental models, and considered how they impact on one's ability to behave creatively. Knowledge can inhibit and constrain or invigorate and expand our creative potential. Couching problems in more abstract terms and confronting unquestioned assumptions can help us tease apart which aspects of our knowledge we ought to embrace and which we should exclude. This can, in turn, place us squarely on the path toward greater creativity.

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VISUALIZING IN A CREATIVE WAY

We have considered how people can use their concepts to formulate creative ideas. Now we examine how mental imagery can enhance creativity. We will also examine how imagery techniques can sometimes help us avoid the influence of conventional concepts when generating a new idea.

We know that people can imagine creative means to find jobs, win at games, solve problems, or put old ideas together to make new ones. Why is imagery so useful in creative thinking? How can our visualization skills be improved to enhance creativity?

Recent studies in the field of cognitive science have explored the nature of mental imagery and have identified many of its salient features, including the role that imagery plays in mentally synthesizing basic elements and parts into completely novel patterns and forms. The studies yield profound insights into the nature of human thought, and they provide new techniques for improving creative visualization.