

## Why a creative brain?

Evolutionary setups for off-line planning of coherent stages.

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The other contributions to this book nicely cover *what* creativity is, *who* has it, and something of *when* and *where*. These elucidations inevitably involve a lot of this-but-not-that category formation, with all the usual hazards of avoiding reification fallacies while clearing away the fog and figuring out what is more and less important.

My role is to focus on creativity's *how* and *why*. And that's more about process than categories. Processes, as R. G. Collingwood noted in 1939, are things which do not begin and end but which turn into one another. We need to know *how* the creativity crank is turned on the time scale of milliseconds to minutes. *Why* is about the evolutionary process over the millennia that made the *how* brain mechanics the way we find them today, operating on the time scale of thought and action.

I will first cover human evolution and what the archaeologists have to say about technological creativity in the past – and the surprising conclusion is that it was very infrequent until about 50,000 years ago, long after the big brain had evolved. Then I will focus on the Darwinian process as it is understood on the millennial time scale of species evolution and the days-to-weeks time scale of the immune response, asking how a similar process could function in our brain circuitry on the time scale of thinking creatively.

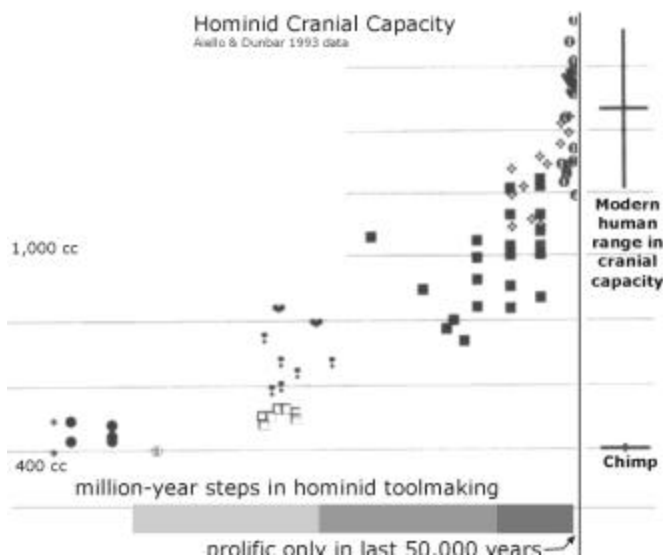
We expect to find the higher forms of creativity building on simpler mechanisms needed for more ordinary innovation and problem-solving. In particular, I will discuss coherence, when everything seems to hang together convincingly. We expect to see our red-flag sense of inconsistency emerging from more mundane applications of judging when novel combinations adequately hang together – say, high payoff situations as when getting set to throw.

The problem with creativity is not in putting together novel mixtures – a little confusion may suffice – but in managing the incoherence. Things often don't hang together properly – as in our night time dreams, full of people, places, and occasions that don't fit together very well. What sort of on-the-fly process does it take to convert such an incoherent mix into a coherent compound, whether it be an on-target movement program or a novel sentence to speak aloud? The bootstrapping of new ideas works much like the immune response or the evolution of a new animal species – except that the neocortical brain circuitry can turn the Darwinian crank a lot faster, on the time scale of thought and action. Few proposals achieve a Perfect Ten when judged against our memories, but we can subconsciously try out variations, using this Darwin Machine for copying competitions among cerebral codes. Eventually, as quality improves, we become conscious of our new invention. It's probably the source of our fascination with discovering hidden order, with imagining how things hang together, seen in getting the joke or doing science.

### **Creativity is an evolutionary newcomer**

If creative brains are such a good thing, why aren't there more of them? For one thing, fumble-and-find works pretty well, most of the time. If animals have something to do that is novel, where they don't have a stored movement plan to call up, they just muddle through, slowly feeling their way.

Fumble-and-find stands in contrast to think-first, doing most of it in your head before moving. A goal, plus some feedback along the way, is adequate – and it mostly obviates the big problem with doing something for the first time, that of it possibly being dangerous. “Feel your way” has a lot of virtues, and nearly all of the animal kingdom has stuck to it



when doing something they haven't done before.

Furthermore, human creativity – an ability to speculate, to shape up quality by bootstrapping from rude beginnings, yet without necessarily acting in the real world – is a recent thing, arriving well after the big brain itself. At least if judging from toolmaking in the archaeological record of the last 2.5 million years since the bipedal apes spun off the bigger-brained *Homo* lineage, there were million-year-long periods of stasis. It wasn't a history of slow, steady improvement and gradually flowering creativity in technique and technology. Brain size was growing, but it is hard to argue that toolmaking was driving it because of these million-year-long periods of stasis in toolmaking.

And consider the use of bone for toolmaking material. You'd think it was great raw material, as there is lots around; it's more common than suitable stones in many places frequented by hunters (which our ancestors were, certainly by early *Homo erectus* times, 1.8 million years ago). The big horns of cape buffalo seem to have been used as digging tools as far back as 2 million years ago, and sticks probably long before that – but neither were used as raw material to craft tools, not for a good two million years after simple stone toolmaking started up 2.6 million years ago. Wooden javelins appear at about 400,000 years ago (about the time of our common ancestor with Neanderthals), but carved bone arrives long after anatomically-modern *Homo sapiens* was on the scene with a big brain, with harpoon tips seen starting about 90,000 years ago. Bashing stones together to get a sharp edge was the main concern for 2.5 million years, with carving only making this late appearance in the last 4 percent of the toolmaking saga (it's the last 1 percent of the time since our last common ancestor with the chimps and bonobos).

So toolmaking creativity doesn't look like the big actor in the ascent of humans – despite our usual notion of a versatile creativity being so important to being human. Are we really forced to consider it as a late, perhaps fortuitous development after other, more important, things were finally in place? There are some alternatives; one important suggestion comes from Michael Tomasello (2000) who noted that “many nonhuman primate individuals regularly produce intelligent behavioral innovations and novelties, but then their groupmates do not engage in the kinds of social learning that would enable, over time, the cultural ratchet to do its work.”

So it might not be a lack of innovation so much as a lack of imitation or teaching; if these were as rare in recent

hominids as they are in apes, the breakthrough at 50,000 years might not be innovation so much as the ways in which it is culturally sustained for long enough to show up in the archaeological record. But Tomasello's escape clause still suggests that technological creativity wasn't very important in evolution until quite recently.

### **Creativity for language instead?**

Since the distinction of anatomically-modern from behaviorally-modern humans was made, the usual explanation has been (Oakley 1951) that language arrived on the scene and changed everything, including creativity. That's the most common explanation offered for what happened about 50,000 years ago.

A more refined version of it (Bickerton 1990, Calvin & Bickerton 2000) says that protolanguage (the vocabulary and unstructured short sentences of modern two-year-olds) could have been gradually developing for a million years – but that the big step up to long, complex sentences (which require structuring by syntax to be disambiguated) is what comes late, somewhat before 50,000 years ago.

Yet language itself is just another example of creativity, once you move beyond stock phrases and start to speak sentences that you've never spoken before. That means you have tried out word combinations, judged them for coherence, and likely improved them offline before uttering them. Thus, some of the most impressive feats of creativity are not even seen as innovation because we all seem to do them so effortlessly.

While language surely makes it easier to spread around the results of creativity and build atop what others have tested, what we really want is the source of both language and non-language creativity. Here I will consider the demands that off-line innovation places on brain circuitry – and how think-first creativity might have taken a major leap forward about 50,000 years ago without any concomitant increase in brain size. Think-first creativity requires a number of abilities, but let me start with planning abilities in general.

### **When an advance plan is needed**

We anticipate our next handhold in climbing a tree, but the really hard versions are when you have to plan multiple stages of the action in advance, rather than just groping your way along while guessing one stage ahead. The driver who

uses grand slalom tactics in freeway traffic, leaving a trail of flashing brake lights in his wake, does not really need higher intellectual function to assist him, only the apelike abilities to swing through the trees, looking ahead to the next handhold. Planning in depth is what I am focusing on here, what you need to imagine several preparatory stages, testing each one off-line and then imagining them one after the other.

Outside of the half-hour time scale of intentions, chimps don't seem to prepare for tomorrow. Innovation is also infrequent and there is no evidence for an ape planning a novel course of action in any depth. If chimps could plan ahead, they would be the terror of Africa (and probably extinct by now) – but they're not. They're aggressive enough, what with their ganglike hit-and-run attacks on an isolated neighbor, five-on-one affairs that leave behind a dying chimp. With a little foresight added to that aggressiveness, chimps could make war on whole groups of neighbors using stockpiling of supplies, practiced maneuvers, and coordinated attacks. But no one sees much evidence of planning in the chimps, and certainly not the sort of planning where two or three *novel* stages have to be worked out in advance of acting – what, in modern warfare, is called “good staff work.” More common examples are seen when planning a college curriculum or a new crop rotation.

Learned staging and innovative on-the-fly staging are, perhaps, different things that evolved at different times. Up until about 400,000 years ago, stone toolmaking consisted of banging away on a stone until it resembled the desired shape, usually one with sharp edges. Then prepared cores were invented, where first one shape was made and then a series of flakes were struck off of it. While this is staged, there is nothing novel about each repeat performance, no mix and match or interpolation – and that's what you need as a setup for on-the-fly creativity that is done off-line as you “get set.”

Many animals can muddle around slowly, feeling their way. Our common ancestor with the Neanderthals could likely routinely stage food preparation as well as toolmaking. But *on-the-fly* creativity that is done *off-line* in coherent *stages* – that's our big challenge. And I have a candidate for what might be the setup, a behavior with a lot of immediate payoffs. It's not at all intuitive, and even sounds mundane. It isn't what our flights of modern creativity lead us to value, but it makes a very good candidate for what might have paid the bills along the way.

### **Innovation during get-set**

What does throwing have to do with creativity? Flinging in the manner of toddlers is not what I have in mind here, nor dart throws or basketball free throws where the idea is to perfectly reproduce the stereotyped memorized commands. Chimps throw as a threat, not as a hunting technique, and they are never seen practicing their technique to improve their accuracy or versatility.

The hard problem with throwing is to use it for targets that are not at one of your standard positions. Compounding this need to be creative is the need to do it right the first time, as otherwise dinner might run away. Here is an example of off-line innovation with a big payoff, in terms of calories consumed and healthy offspring.

Throwing (and other ballistic movements such as clubbing, kicking, and hammering – and, for that matter, spitting) is over-and-done in an eighth of a second. You simply cannot feel your way into this, as the feedback takes so long. It takes about an eighth of a second for spinal reflexes to even begin to correct a perturbation in the arm. Since a dart throw only lasts about an eighth of a second, it is entirely ballistic, unguided by second thoughts after you start. So the feel-your-way tactics that most animals use won't work here, except in the slow positioning that precedes the rapid ballistic movement.

And planning a throw has some nested stages, reminiscent of syntax. The highest velocity action is in the wrist movement, but planning it requires you to take account of what the elbow is doing: wrist flicks, where mistakes matter most, are nested inside elbow uncocking. Yet elbow planning needs to know what the shoulder is doing, and the shoulder too has a forward velocity due to what the whole trunk is doing. For any given target distance and elevation, there are a hundreds of combinations of wrist-elbow-shoulder-trunk movements which will get the projectile on target – but they are hidden in a sea of millions of wrong combinations, any one of which will cause dinner to escape.

You need a *coherent* plan: all of the plans (and there are about a hundred muscles involved) have to hang together. And, if the target is not at one of your well-rehearsed distances, you must make a *novel, staged, coherent* plan. In this case, throwing isn't mundane; it is indeed starting to sound a lot like the kind of creativity that we otherwise care most about – and especially like the everyday coherent plans for novel structured sentences.

## **The Darwinian process**

The problem with creativity is not mixing and matching. Variability usually comes for free in most biological systems. Mixups are easy. The problem is incoherence, where things just don't hang together properly – as in our nighttime dreams, full of people, places, and occasions that never occur together in real life. What sort of process does it take to convert that kind of raw material into coherent collections, whether it be an on-target movement program, a novel sentence to speak aloud, or a sculpture?

The only process we know in nature that routinely achieves coherent results from incoherent raw materials is the one Darwin discovered. This quality bootstrap is not only seen at work on the millennial time scale of species evolution but also on the days-to-weeks time scale of the immune response. Can brain circuitry run a version of it on the time scale of thought and action, shaping up a good-enough movement program for ballistic movements? And perhaps other creative sequences, such as novel sentences?

It is surprising that so few discussions of creativity focus on the mechanics of this well-known process for successful innovation, particularly when there are not other good examples of an algorithmic quality-improvement process. Although creativity may seem spontaneous, without perceived antecedents, it may nonetheless reflect an underlying process of the refinement of candidates.

It was unfortunate that Charles Darwin named his theory “natural selection” as that is only one of essentials of the process. Variations, then selection, then more variations centered on the more successful (at surviving, finding mates, rearing offspring) of the first round. Keep doing this, and some very improbable things of high quality can gradually be shaped up.

One can summarize Darwin's bootstrapping process in various ways. A century ago, Alfred Russel Wallace emphasized variation, selection, and inheritance. (It reminds me of a three-legged stool: evolution takes all of them to stand up.) But as I explain at more length in *A Brain for All Seasons* (from which this section is adapted), there are some hidden biological assumptions in that three-part summary. When trying to make the list a little more abstract to encompass non-biological possibilities, I wound up listing six ingredients that are essential (in the sense that if you're missing any one of them, you're not likely to see much progress):

1. There's a pattern of some sort (a string of DNA bases called a gene is the most familiar such pattern, though a cultural meme – ideas, tunes – may also do nicely).
2. Copies can be made of this pattern (indeed the minimal pattern that can be semi-faithfully copied tends to define the pattern of interest).
3. Variations occur, typically from copying errors or superpositions, more rarely from a point mutation in an original pattern.
4. A population of one variant competes with a population of another variant for occupation of a space (bluegrass competing against crabgrass for space in my backyard is an example of a copying competition).
5. There is a multifaceted environment that makes one pattern's population able to occupy a higher fraction of the space than the other (for grass, it's how often you water it, trim it, fertilize it, freeze it, and walk on it). This is the “natural selection” aspect for which Darwin named his theory, but it's only one of six essential ingredients.
6. And finally, the next round of variations are centered on the patterns that proved somewhat more successful in the prior copying competition. (The “inheritance principle”.)

Try leaving one of these out, and your quality improvement lasts only for the current generation – or it wanders aimlessly, only weakly directed by natural selection.

Many processes loosely called “Darwinian” have only a few of these essentials, as in the selective survival of some neural connections in the brain during development (a third of cortical connections are edited out during childhood). Yes, there is natural selection producing a useful pattern – but there are no copies, no populations competing, and there is no inheritance principle to promote “progress” over the generations. Half a loaf is better than none, but this is one of these committees that doesn't “get up and fly” unless all the members are present.

### **Speeding up the Darwinian process**

And it flies even faster with a few optional members. There are some things that, while they aren't essential in the same way, affect the rate at which evolutionary change can occur. There are at least five things that speed up evolution; while I will use examples from the outside world to illustrate them, they all have counterparts in the brain circuitry for running the Darwinian process.

First is speciation, where a population becomes resistant to successful breeding with its parent population and thus preserves its new adaptations from being diluted by

unimproved immigrants. The crank now has a ratchet.

Then there is sex (systematic means of creating variety by shuffling and recombination – Don't leave variations to chance!).

Splitting a population up into islands (that temporarily promote inbreeding and limit competition from outsiders) can do wonders.

Another prominent speedup is when you have empty niches to fill (where competition is temporarily suspended and the resources so rich that even oddities get a chance to grow up and reproduce).

Climate fluctuations, whatever they may do via culling, also promote island formation and empty niches quite vigorously on occasion, and so may temporarily speed up the pace of evolution.

Some optional elements slow down evolution: “grooves” develop, ruts from which variations cannot effectively escape without causing fatal errors in development. And the milder variations simply backslide, so the species average doesn't drift much. Similar stabilization is perhaps what has happened with “living fossil” species that remain largely unchanged for extremely long periods.

Are there brain circuits capable of running this sort of Darwinian process on the time scale of thought and action – say, milliseconds to minutes? That was the topic of my 1996 book *The Cerebral Code* and, while the answer appears to be yes for the recurrent excitatory circuits of the superficial layers of neocortex, we still don't know how much of the neocortex makes use of this ability and when. Once, during a period of fetal or infant tune up? All the time, in all areas of neocortex? Where and when await experimental evidence, and the more interesting question – how to you make subroutines out of the successful plans, so as to avoid running through the whole Darwinian copying competition on subsequent occasions – hasn't been elucidated at all.

### **New uses for old things**

But let us assume that some brain circuits are capable of running such a process for making multistage coherent plans, and judging them for quality against your memory of what's reasonable and safe. Can you use them for other movement sequences than just hand-arm? Though some of the best-understood regions of the brain such as primary visual cortex seem rather dedicated to a specialty, much of association cortex seems multifunctional. Certainly there is much evidence suggesting that oral-facial movement

planning can overlap with that for hand-arm – and with that for language, both sensory and motor aspects (Calvin & Ojemann 1994).

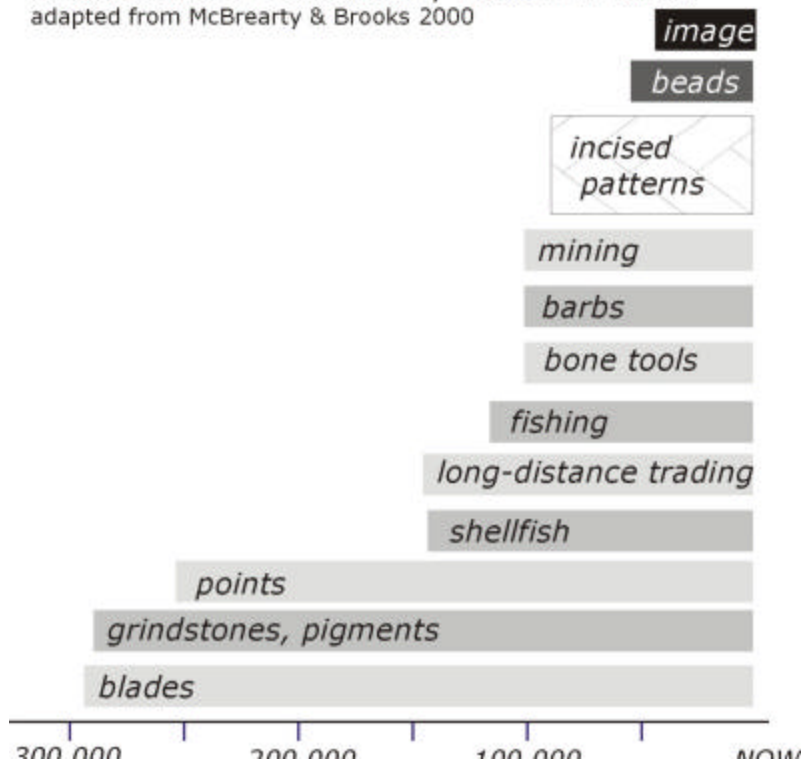
That suggests some relevant parts of association cortex ought to be at ease with secondary uses of specializations “paid for” by other considerations. It’s much like when wheelchair considerations paid for curb cuts but soon 99 percent of their use was for things that would never have paid their way – baby carriages, skateboards, wheeled suitcases, bicycles, and so on. Maybe one of those secondary uses will eventually pay for further improvements just as wheeled-suitcase use has “paid” for widening of curb cuts at airports, but pay-before-using is not required. The “free lunch” is alive and well in both urban architecture and brain circuitry.

When did spare-time uses develop for the movement planning neural machinery for throwing? Hammering was likely the earliest, though with shared machinery, you can have coevolution with synergies: better throwing might improve, in passing, the ability to hammer accurately. And vice versa.

When did the multistage planning abilities get used on a different time scale, say the hours-to-days time scale of an agenda that you keep in mind and revisit, to monitor progress and revise? That’s harder but many people would note that an ability to live in the temperate mid-latitudes requires getting through the months called wintertime when most plants are dormant and shelter is essential. Clearly

### Antecedents to Behaviorally Modern in Africa

adapted from McBrearty & Brooks 2000



*Homo erectus* managed this by 1.7 million years ago in the Causacus Mountains, at the same latitude as Chicago.

When did secondary use spread from hand-arm movements to oral-facial ones? Or to making coherent combinations of more symbolic stuff, not just movement commands? One candidate for both is at 50,000 years ago, as that's when behaviorally-modern capabilities seem to have kicked in and launched behaviorally-modern people out of Africa and around the world.

Most aspects of modernity cannot be seen or dated in the archaeological record, or at least not until other secondary developments (such as settlements at 10,000 years ago, or writing at 5,000 years ago) come along. But most have an aspect of creativity to them, so let me survey some of them.

### **Long sentences and coherence**

The big step up is probably not to symbolic expression itself, as has been assumed for the last half century. More likely, the big step is from symbols in short sentences to symbols in long sentences that must utilize syntax (Calvin & Bickerton, 2000). You don't need syntax for the short sentences of the modern toddler. But without some structuring conventions, you couldn't say "Who did what to whom, why, and how" much faster than you could pantomime it all. The relationship between four or more words is simply too ambiguous without some scaffolding to hold them in place, some structuring conventions which we call grammar or syntax.

A spoken or signed vocabulary, extending well beyond the few-dozen items in a great apes' repertoire, might have gradually come along over a few million years, and the creation of short sentences could have allowed combinations to have meanings that the individual words did not. But the step up to syntax is a big one, as it involves recursion. In their third year, provided they have a structured language to listen or watch, modern children discover how to structure longer sentences, nesting phrases and clauses inside one another ("I think I saw him leave to go home" is three sentences nested inside a fourth, like Russian dolls), plus the general rules for designating past tense and making plurals in whatever language they have been exposed to.

Other aspects of structured thought follow: multi-stage planning, games with rules that constrain possible moves, chains of logic, structured music – and a fascination with discovering hidden order, with imagining how things hang

together. Indeed, our brain may have a common way of handling structured stuff, one of the reasons why that some functions might come (and go, in strokes or senility) as a package deal.

But even if the ability to order our thoughts was a package deal, it still takes something more in order to make structured thought more than just an ability to mentally maintain a deep maze. Without an ability to judge coherence, and improve on it over and over before acting, you cannot imagine explanatory scenarios, nor project very far into the future. Creativity hinges on that. Pasteur's dictum, "Chance favors the prepared mind," illustrates this interplay between variations and memories of prior combinations.

Major parts of this structured suite (not just syntax) were likely invented sometime before 50,000 years ago, and provided the giant step up to the modern mind of *Homo sapiens sapiens*. Before then, our ancestors mostly had a here-and-now mental life with little structured interpretation of the past. And not much on-the-fly contingent planning. They saw death every day but, without much ability to speculate about the future, they couldn't conceive of their own mortality.

But levels are the real stuff of creativity, so let me give an appreciation of one of the greatest feats of creativity: the everyday emergence of new levels of organization.

### **Creating new levels of organization**

Level of organization is a common concept in the sciences. It is best defined by certain functional properties (Calvin & Bickerton, 2000), not anatomy. As an example of four levels, *fleece* is organized into *yarn*, which is woven into *cloth*, which can be arranged into *clothing*. Each of these levels of organization is transiently stable, with ratchet-like mechanisms that prevent backsliding: fabrics are woven, to prevent their disorganization into so much yarn; yarn is spun, to keep it from backsliding into fleece.

A proper level is also characterized by "causal decoupling" from adjacent levels (Pagels, 1988); it's a "study unto itself." For example, you can weave without understanding how to spin yarn (or make clothing). Indeed, Dmitri Mendeleev figured out the periodic table of the elements without knowing any of the underlying quantum mechanics or the overlying stereochemistry, and most of the natural sciences need only several levels of organization. There are, however, at least a dozen levels of

organization within the neurosciences — all of the way up from genes for ion channels to the emergent properties of cortical neural circuits. And, if we invent a metaphor, we temporarily create yet another level.

Words are often simple categories. In the animal world, they are usually emotional utterances, such as the chimpanzee's "What's that?" or "Get away from that!" equivalents, though they can occasionally be interpreted as nouns ("snake" or "eagle"). We humans can combine utterances for a new meaning, say "That's big." In addition to such relationships, we can compare, say "This is bigger than that." We can even build a new level, that of relationships between relationships, when we say "Bigger is better." It is this on-the-fly construction of a new level, as when we find an analogy, that is what makes human cognition so open-ended, so unlike anything seen elsewhere in evolution.

Mental life can pyramid a number of levels, thereby creating structure. We see the pyramiding of levels as babies encounter the patterns of the world around them. They first pick up the short sound units of speech (phonemes), then the patterns of them called words, then the patterns within strings of words we call syntax, then the patterns of minutes-long strings of sentences called narratives (whereupon she will start expecting a proper ending for her bedtime story). By the time you encounter the opening lines of James Joyce's *Ulysses*, you will need to imagine several levels at once:

"Stately, plump Buck Mulligan came from the stairhead, bearing a bowl of lather on which a mirror and a razor lay crossed. A yellow dressinggown, ungirdled, was sustained gently behind him by the mild morning air. He held the bowl aloft and intoned: Introibo ad altare Dei."

There's the level of the physical setting (piecing together an old Martello gun tower overlooking Dublin Bay with a full-of-himself medical student about to shave). But there's also the more abstract level of metaphor. (Ceremonial words and a deliberate pace – but ungirdled gown and an offering of lather?)

So much of our intellectual task, not just in reading Joyce but in interpreting everyday conversation, is to locate appropriate levels of meaning between the concreteness of objects and the various levels of category, relationships, and metaphor. You usually cannot get the joke without locating the correct level of organization to which it refers, and it is often the alternative interpretations at different possible

levels that makes it so funny. Creativity often involves the interplay between levels of organization.

Two tasks are needed to keep this level building from becoming nonsense. The first is to judge new associations for coherence: do they all hang together in a reasonable, safe way? (To start with, most are surely as incoherent as our nighttime dreams.) Awake, it's an off-line search for coherence, for combinations that "hang together" particularly well. Sometimes this provides an emergent property: the committee can do something that all the separate parts couldn't. It can be like adding a capstone to an arch, which permits the other stones to support themselves without scaffolding – as a committee, they can defy gravity.

Second, to spend more time at the more abstract levels in an intellectual house of cards, the prior ones usually have to be sufficiently shored up to prevent backsliding. Poets, in order to compare two candidate metaphors, have to build a lot of scaffolding.

We have achieved an extraordinary ability to pretend, fantasize, lie, deceive, contrast alternatives, and simulate. Our minds can operate on the unreal, and the formation of unreal, blended spaces says a lot about our creativity. Let me close with this description by Mark Turner in *The Literary Mind*:

Certainly there is considerable evidence that blending is a mainstay of early childhood thought. A two-year-old child who is leading a balloon around on a string may say, pointing to the balloon, "This is my imagination dog." When asked how tall it is, she says, "This high," holding her hand slightly higher than the top of the balloon. "These," she says, pointing at two spots just above the balloon, "are its ears." This is a complicated blend of attributes shared by a dog on a leash and a balloon on a string. It is dynamic, temporary, constructed for local purposes, formed on the basis of image schemas, and extraordinarily impressive. It is also just what two-year-old children do all day long. True, we relegate it to the realm of fantasy because it is an impossible blended space, but such spaces seem to be indispensable to thought generally and to be sites of the construction of meanings that bear on what we take to be reality.

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