2 Surprise

When I was in sixth grade, we held a surprise party for our teacher, Ms. Bradley. One of my classmate's parents had invited Ms. Bradley to dinner. Hiding in the basement was my entire sixth-grade class. Under the pretense that dinner wasn't yet ready, Ms. Bradley was led down into the darkened room. When the lights came on we all shouted "SURPRISE!" at the top of our lungs. The effect couldn't have been more satisfying to a child's mind: Ms. Bradley nearly jumped out of her skin. There was an expression of sheer terror on her face: her chin had dropped, leaving her mouth wide open, and the whites of her eyes were visible all the way around her pupils. But the expression of terror quickly dissolved into laughter as she regained her composure.

When a surprising event occurs, two brain processes are initiated: a rapid reaction response and a slower appraisal response. Research by Joseph LeDoux and his colleagues at New York University has helped to trace the corresponding pathways through the brain.[1] Figure 2.1 provides a schematic diagram of the reaction and appraisal tracks. Whether the stimulus is visual or auditory in origin, information is first relayed to the thalamus, where some basic processing occurs. At this point the fast and slow tracks are known to diverge. The fast track proceeds directly to the amygdala, which plays an important role in the assignment of affective significance to sensory stimuli. If fear is evoked, activity can be seen in the midbrain periaqueductal gray—which coordinates a number of defense responses. In addition, the paragigantocellularis lateralis will be activated. This is a region of the brain that initiates changes to the viscera that contribute to the sensation of fear. When an event makes you feel something in the pit of your stomach, it is the paragigantocellularis lateralis that is responsible.

The slow track amounts to a long detour between the thalamus and the amygdala. The detour here is via the cerebral cortex—the massive outer layer of the brain, which, among other things, is responsible for conscious thought. Here the stimulus causes activation throughout large areas of the cortex, especially in the frontal lobe region—areas associated with cognitive rumination and evaluation. All sorts of complex social,

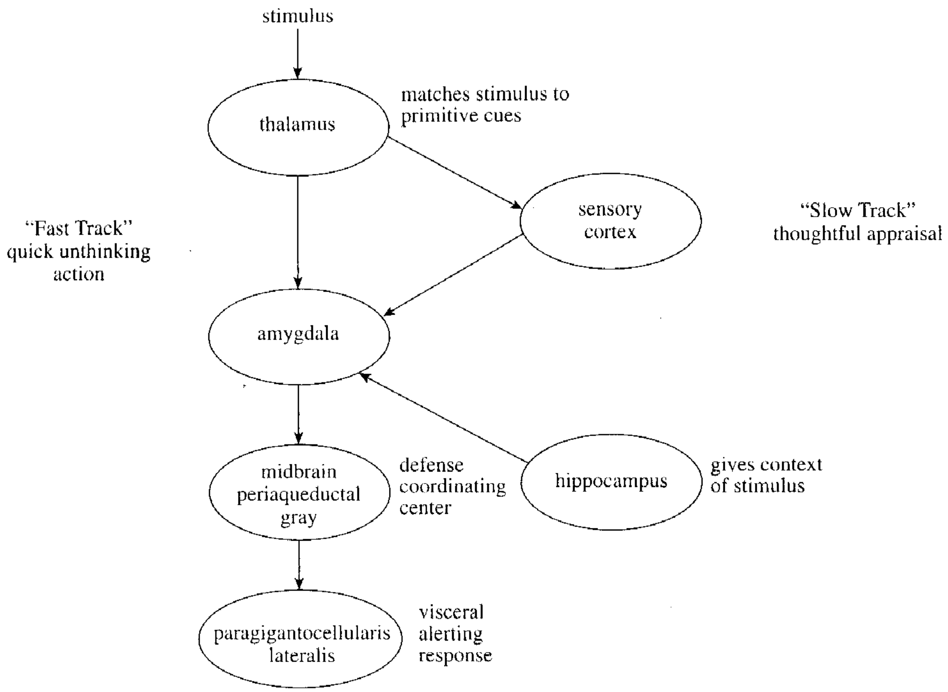

Figure 2.1
Schematic diagram of the brain mechanisms involved in the fear response. Concurrent fast and slow pathways are activated. The fast track involves a direct connection between the thalamus and the amygdala. The slow track leads through the sensory cortex—the large mass located on the exterior surface of the brain.

environmental, and behavioral considerations are brought to bear in appraising the situation. All of this neural activity makes this track the more complicated pathway.

The fast and slow pathways converge in the lateral nucleus of the amygdala. In fact, the two pathways converge onto single neurons in the amygdala.[2] If the slow track leads to the assessment that fear is unwarranted, then the cortex will generate an inhibitory signal that effectively turns off the amygdala and arrests the fear response. Compared with reaction responses, such cognitive processes result in a more accurate, nuanced, and realistic appraisal of dangers, risks, or opportunities afforded by some situation. Unfortunately, this appraisal process is comparatively slow.

For both the fast and slow pathways, the context of the stimulus is known to influence the fear response. Several studies have shown that the context for fear associations depends on the hippocampus. That is, the hippocampus helps us interpret the fear-evoking stimulus.[3]

As noted, the rapid reaction response to surprise assumes the worst. The body responds quickly—under the presumption that the outcome is bad and that the body must belatedly rally resources to deal with an unanticipated situation. When it comes to the unexpected, our physiological reflexes reveal that biology is deeply suspicious and pessimistic: bodies don't like surprises.

One consequence of this rapid reaction response to surprise is activation of the sympathetic nervous system: heart rate increases, and there is increased perspiration, increased glucose uptake, and an increase in the rate and volume of respiration. The purpose of the respiratory response is to bathe the body's tissues in oxygen (and purge carbon dioxide) in preparation for a possibly major energy expenditure. In addition to this increase in arousal, another consequence of surprise is an increase in attention. Sensory systems become more acute. Irrelevant thoughts are purged and attentional resources are focused on the immediate events.

The heightened arousal and attention associated with surprise can be observed directly in the characteristic facial expression for surprise. Recall that Ms. Bradley's chin dropped so that her mouth was wide open, and her eyelids were fully retracted producing a "wide-eyed" look. The open mouth facilitates respiration, which is a component of raising arousal. The open eyes facilitate visual perception, which is a component of increased attentiveness.

Contrastive Valence

Surprising people for fun appears to be a cross-cultural universal.[4] Ronald Simons has documented many instances of "recreational" surprise in various cultures. Most cultures have an equivalent of the "peek-a-boo" interaction between parents and infants, and in nearly all cultures children take delight in sneaking up on each other.

It is not simply the case that surprises are fun for those doing the surprising. In some circumstances (such as Ms. Bradley's surprise party) surprises can also be fun for the person being surprised. But the observation that at least some surprises can be pleasurable raises a biological puzzle. Recall that the purpose of expectation is to enhance readiness. The phenomenon of "surprise" represents a failure of expectation. From a biological perspective, surprise is *always* a bad thing. Even when the surprising outcome turns out to be good, failing to anticipate the outcome means that the brain has failed to provide useful information about possible futures. Predictive failures are therefore cause for biological alarm. If an animal is to be prepared for the future, the best surprise is no surprise.

So if surprise is biologically bad, how is it possible for some surprises to activate the physiological machinery for pleasure? How can people possibly enjoy being surprised? It turns out that an answer to this question can be found on any basketball court. Consider the following experiment carried out by psychologist Peter McGraw.[5] McGraw asked amateur basketball players to take shots from different locations around the court. Before each shot, the player was asked to estimate the likelihood of scoring a basket. Following each shot, the player rated how good he or she felt. As you would expect, players are happiest when they successfully make a shot and are unhappy when they miss a shot. Emotions are positively valenced for positively appraised outcomes and negatively valenced for negatively appraised outcomes. However, the degree of satisfaction or dissatisfaction is also related to the player's expectation. McGraw found that basketball players experienced the greatest unhappiness when they missed shots judged easy, and were happiest when they scored baskets judged to be difficult. The magnitude of the emotional response is amplified when there is a large contrast between predicted and actual outcome. In general, *unexpected* fortune or misfortune causes the biggest emotional responses.[6] That is, low expectation amplifies the emotional response to the outcome.

When we are surprised, a limbic contrast will sometimes arise between the reaction response and the ensuing appraisal response. The fast biological response to surprise is perpetually negative. But the slower appraisal response might be neutral or even positive. At Ms. Bradley's surprise party, the momentary terror she experienced was quickly displaced by a highly positive appraisal response. Her amygdala was switched on and then abruptly switched off. As with McGraw's basketball players, it was the limbic contrast that rendered the experience so powerful. In less than a second, Ms. Bradley's brain went from experiencing profound terror to happy celebration.

In the case of McGraw's basketball players, the limbic contrast was between the prediction response and the appraisal response. In the case of Ms. Bradley's surprise party, there was similarly a contrast between the prediction and appraisal responses, but the main limbic contrast was between the (very negative) reaction response and the (very positive) appraisal response.

Limbic contrasts between the fast and slow pathways are not limited to the extreme circumstances of a surprise party. In our daily lives we experience hundreds of small moments of surprise: a telephone rings, a pen runs out of ink, the car ahead changes lanes, a petal falls from a cut flower. Many of these episodes fail to reach conscious awareness. Most are ultimately appraised as innocuous.

The interaction of the fast and slow pathways has repercussions for how listeners experience sound. If a nominally unpleasant sound is not expected by a listener, then the sound will be perceived as even more unpleasant or annoying. Conversely, if a nominally pleasant sound is not expected by a listener, it will tend to be perceived as more pleasant. A lengthy dissonant passage is likely to lead listeners to expect further dissonant sonorities. If the music shifts toward a more consonant texture, then the resulting contrast will tend to evoke a pleasing effect that can be greater than experiencing only the consonant passage.

More interestingly, even neutrally appraised sounds have the capactiy to generate limbic contrast. Whether or not a sound is regarded as inherently pleasant or unpleasant, if it is unexpected, it is capable of evoking a negatively valenced prediction response—which may contrast with an ensuing neutral appraisal.

An apparent problem for the contrastive valence theory is accounting for why an unexpected good outcome would be experienced as more positively valenced than an expected good outcome. In the case of an expected good outcome, a person should feel good about the outcome and should also feel good about the predictive accuracy. In the case of an unexpected good outcome, a person should feel good about the outcome but also feel bad about the poor predictive accuracy. Why then does an unexpected good outcome sometimes evoke a more positive emotion than an expected good outcome? It is possible that the contrast between the positive appraisal and negative reaction is the more powerful effect. But if so, it would be maladaptive to consistently experience a positive emotion whenever one's predictions prove wrong. Perhaps the only important lessons for an organism to learn occur when a wrong prediction accompanies a negative appraisal of the outcome.

A better understanding of the phenomenon comes from looking at some of the physiological research. When we experience stress, it is typically accompanied by the release of endogenous opiates such as endorphins. These natural opiates produce an analgesic effect that reduces the experience of pain. You've probably experienced a panic situation, such as where you've had to run to catch a bus. Only after you are settled in the bus do you realize that you inadvertently cut yourself in your frantic rush. Oddly, the pain is much more subdued than if the same injury had been inflicted while at rest. That is, the energetic panic had somehow attenuated the experience of pain. Working at Stanford University, Albert Bandura, Delia Cioffi, Barr Taylor, and Mary Brouillard carried out an experiment where individuals were artificially induced to fail at some task. Half of these individuals were administered a saline solution while the other half received naloxone—an opiate receptor antagonist that blocks the effect of any endorphins present. The participants were then given a test that measured their tolerance for pain. Those individuals who had received naloxone were significantly less pain tolerant, indicating that the stress caused by failing at the task had resulted in a release of endogenous opiates.[7]

The body appears to release opiates whenever we experience a negatively valenced emotion such as pain or fear. Suppose that a wild bear appeared and injured you. Immediately, analgesic opiates are released by the body to counteract the pain and allow you to continue to function. Now, suppose that it turned out that you weren't actually injured, but the opiates were released anyway. The net result is simply the opiate release—and the ensuing pleasant feelings. The physiological origin of contrastive valence might follow a path akin to this sequence of events.

The potential for increased pleasure provided by contrastive valence might explain a number of seemingly peculiar conscious strategies people use when mentally preparing for future outcomes. Recall that the imagination response occurs in the pre-outcome epoch—prior to the outcome event. Normally, the imagination response serves a motivational function. By imagining different outcomes (and experiencing a foretaste of the feelings associated with these outcomes) we are encouraged to take actions that will reduce future negative outcomes and increase the likelihood of future positive outcomes. Even for the most certain positive outcomes, if time permits, we will have an opportunity to consider the possibility that the positive outcome will not happen. The imagination response for such scenarios is sobering. We realize that even at the cost of reducing the predictive accuracy, it is better to lower the subjective probability of a positive outcome in order to mute the bad emotions that might ensue from an unexpected negative outcome.

Support for this view comes from a common mental strategy. When a good outcome seems highly probable, a person will sometimes mentally deny or minimize the likelihood of the positive result. ("Everyone seems certain that Caroline will agree to marry me, but I think there is a real chance that she will say no.") This conscious mental strategy has the effect of reducing the magnitude of the negative feelings should a negative outcome ensue, while simultaneously increasing the pleasure evoked by a positive outcome. Similarly, people will occasionally exaggerate negative predictions. ("My coat is ruined; I bet that stain will *never* come out.")

This view is reinforced by the reverse scenarios—found in the experience of *Schadenfreude*—pleasure in others' misfortune. When a rival seems poised for failure, we may minimize the likelihood of their negative outcome ("Aaron is certain to escape punishment for what he did"). This conscious mental strategy will minimize the disappointment if our rival escapes the negative outcome, and increase the pleasurable *Schadenfreude* should the negative outcome be realized. Conversely, when a rival seems poised for success, we may amplify the likelihood of their success ("Barbara is certain to inherit the house"). This will maximize the *Schadenfreude* if the rival in fact does not succeed, and increase the positively valenced prediction response if the outcome for our rival is positive ("I absolutely *knew* that Barbara was going to get the house").

Notice that these strategies are necessarily conscious. They supplant the underlying unconscious intuitions about the likelihood of various events and intentionally bias the subjective probabilities in order to maximize positively valenced emotional states. Since these strategies require conscious rumination, a certain amount of time is needed in order for a person to formulate the strategy. When events unfold quickly, there is insufficient time to arrange these strategies. By way of example, consider once again the case of the basketball players predicting the success of sinking baskets. The theory of contrastive valence can be used to make the following prediction. After a basketball player has predicted the likelihood of making a shot, suppose we stop the player from shooting. We then ask the player to pause and reflect again on the shot: "With a moment's thought here, would you like to consider revising your estimate of the likelihood of making this shot?" My prediction is that the players will tend to reduce the probability of making the shot. That is, in general, the longer the time interval for contemplation, the lower the assessed probability of a positive outcome. Moreover, if a large (monetary) reward is offered for completing a shot, I predict that the effect will be magnified: the larger the monetary reward, the greater the likelihood that the assessed probability will drop below the objective empirical likelihood of making the shot. That is, people will tend to adopt an overtly pessimistic attitude in order to minimize possible disappointment and maximize future pleasure.

All of this presumes a "contrastive valence" theory of the magnitude of positive and negative emotions. How we ultimately feel about an event is not simply tied to an appraisal of some absolute benefit or penalty associated with that event. Our feelings also seem to depend on limbic contrast.[8] This is not a new insight. In his *Essay on Human Understanding*, John Locke spoke of the pleasure arising from the removal or attenuation of pain. Edmund Burke explicitly argued that the aesthetic experience of the "sublime" depends on an initial sensation of fear that is ultimately appraised as inconsequential. Nor do these ideas originate with these eighteenth-century European philosophers. Throughout history, sages have recognized that pleasure is enhanced by contrast: happiness is not so much a state of being as it is a state of becoming. People who fast periodically probably benefit from contrastive valence. As the Spartans understood, hunger is the best spice.

Three Flavors of Surprise

Listening to music can give rise to an enormous range of emotions.[9] Music can engender a joyous exuberance or transport us into a deep sadness. It can evoke a calm serenity or generate spine-tingling chills. It can lead to a sense of ominous darkness or convey a mysterious sense of awe and wonder. Music can even cause listeners to laugh out loud.

Apart from these strong "whiz-bang" emotions, music is also able to generate a wealth of "microemotions"—more subdued or muted feelings that are not easy to describe but occur more frequently while listening to music. These more nuanced feelings will be considered in later chapters. For the remainder of this chapter I would like to focus on three strong emotions that are closely linked to surprise: *laughter*, *awe*, and *frisson*. *Laughter* is a state of jocular amusement that is characterized by a distinctive "ha-ha-ha" vocalization. *Awe* is a state of astonishment or wonder that may cause a person to gasp. *Frisson* is the feeling you have when "chills" run up and down your spine and the hair stands up on the back of your neck. (All of these responses will be described more carefully later.)

These strong emotions are not common while listening to music, but when they occur they are memorable. Such emotions are typically sparked by particular musical moments or passages. Of course, not all listeners will respond to these passages in the same way, and even a single individual listener may not have the same emotional experience each time the passage is encountered. When they are evoked, however, these emotions are distinctly pleasurable and so listeners often seek out these experiences. Although *laughter*, *awe*, and *frisson* appear to be very different from one another, I will suggest that they share a deep biological kinship. We will see that each of these emotions is related to a violation of expectation. All three are specialized varieties of surprise.

Extreme surprises lead to the characteristic "surprise" facial expression. Interestingly, the "surprise" expression is the same as the one for horror.[10] The common element is simple fear. When in a fearful state, an animal has recourse to one of three behaviors. One response is to stand one's ground and attempt to defeat, disarm, or neutralize the danger; the goal here is to prevail over the fear-inducing situation. Another response is to run away as quickly as possible; the goal here is to escape the fear-inducing situation. A third response is to hide by remaining perfectly immobile and quiet; the goal here is to escape notice while the fear-inducing situation passes. These three primordial behaviors of fight, flight, and freeze can be observed throughout the animal kingdom. Even insects respond to danger by generating one of these three behaviors.

In everyday life, these responses are rarely manifested as full-blown behaviors. Instead, they are occasionally glimpsed as momentary or fleeting states. In the case of the surprise party, the person being surprised will often exhibit the characteristic "surprise" face with the gaping mouth and wide-open eyes. The "surprised" facial expression can pass in the blink of an eye. It is sometimes so quick, that it is apparent only later when viewed on video. The surprised expression is soon replaced by smiles and laughter as the celebrated individual realizes the true meaning of the unanticipated event. But in that first brief moment of fear lies much that is important.

Laughter—A Pleasurable Panting

In chapter 14 we will see examples of musical passages that cause listeners to laugh out loud. People don't often laugh while listening to music, but musically induced laughter does occur from time to time. Occasionally, composers explicitly set out to create works that provoke laughter—such as Mozart's *Ein musikalischer Spass* ("A Musical Joke"), Haydn's string quartet opus 33, no. 2 ("The Joke"), or Peter Schickele's wacky *Pervertimento for Bagpipes, Bicycle and Balloons*. In chapter 14 we will see evidence that whenever music causes listeners to laugh, the response can be traced to a massive violation of expectation. But for now, let's simply accept my claim that musically induced laughter is one of the responses a listener can experience when surprised.

What is it about some violations of expectation that will cause listeners to laugh? A tempting answer is to say that the violations are "humorous." But this begs the question. Consider a more literal version of our question: Why do people sometimes make a "ha-ha-ha" sound in response to violated expectations? Why don't listeners make a "hissing" sound, grit their teeth, or tug on their earlobes? What is it about violated expectations that can evoke the distinctive "ha-ha-ha" vocalization we call laughter?

Scientific studies on laughter can help answer this question—but the story is a little circuitous.[11] Perhaps the single most important lesson from research on laughing is that laughter is predominantly a *social* response. Robert Provine estimates that people are thirty times more likely to laugh in the presence of another person than when they are alone.[12] Field studies have established that most laughter is not in response to humor. Social inferiors laugh more in the presence of their social superiors. Social inferiors are also more likely to laugh at the instigation of social superiors than vice versa. For those of us who love to laugh, the scientific research on laughter seems depressing: the principal function of laughter seems to be to dissipate social fears. Laughter is a common response to humor, but humor is not necessary for laughter. For example, people frequently laugh at the misfortunes of their enemies, or laugh nervously in the face of danger.

Although laughter is predominantly a social phenomenon, the laughter response itself is innate rather than learned. All over the world, people laugh with a characteristic "ha-ha-ha . . ."[13] Even congenitally deaf people who have never heard anyone laugh make the same sound. Of course there are many variations on a theme. Some people make little sound—simply allowing their chest to jiggle in paroxysms of laughter ("chuckling"). Other people squeal, bellow, or roar. Yet others exhibit all manner of giggling, yukking, snickering, and snorting. Despite these variations, the basic laughter pattern remains.

Provine describes laughter as a "punctuated exhaling." The onset-to-onset time between "ha's" occurs at regular intervals of about 210 milliseconds. If the vocalization is high pitched and quiet, the sound is regarded as "giggling." If the mouth remains closed during laughing, the sound is better described as "snickering." If the mouth opens and closes in synchrony with the "ha's" then the sound becomes one of "yukking." If the mouth is rounded and remains open, then the sound is modified to a distinctly Santa-like "ho-ho-ho." Each laugh-phrase is followed by a deep inhalation. If the inhalation relies on the nose alone, then sometimes a snorelike vibration of the soft palet will cause a distinctive "snorting" sound (often to the embarrassment of the person laughing). Sometimes the laughter is preceded by a high-pitched squeal. In general, however, the basic laughter pattern consists of a punctuated exhaling that occurs at a rate of roughly five times per second.[14]

Humans are not the only animals that laugh. Recognizably laughlike responses are also observed in chimpanzees, bonobos, orangutans, and gorillas. For example, tickling a young chimpanzee will typically cause the chimp to produce a rapid "oo-oo-oo-oo" sound. Similar sounds are produced during rough-and-tumble play such as when an animal is being chased by a playmate. Interestingly, the rate of such punctuated breathing is comparable to the rate found in human laughter. However, the laughter of chimpanzees, bonobos, orangutans, and gorillas differs in one important respect from that of humans. Humans laugh by exhaling only. The "oo-oo-oo-oo" sound of nonhuman primates involves a rapid alternation of inhaling and exhaling that doubles the tempo of the vocalizations to about ten per second.[15]

Robert Provine has argued that the human exhale-only version of laughter is a recent evolutionary development since the inhale–exhale version is shared by the other primates. Says Provine, "The human variant with its looser respiratory-vocal coupling evolved sometime after we branched from chimpanzees about six million years ago. Evidence of the primacy of the chimp form comes from the identification of chimplike laughter in orangutans and gorillas, apes that split off from the chimpanzee/human line several million years before chimpanzees and humans diverged."[16]

The inhale–exhale laughter of chimpanzees, bonobos, orangutans, and gorillas is essentially a form of *panting*. In fact, when Provine played recordings to university students and asked them to identify the sounds, the most common response was to describe the sounds as "panting." Going beyond Provine's research, we might observe that panting is a common component of physiological arousal: panting prepares an animal for physical exertion by drawing in large quantitites of oxygen and expelling carbon dioxide. When an animal fails to anticipate an event, this failure represents a potential danger. Like increased heart rate and increased perspiration, panting is a wholly appropriate response to surprise.

There are different types of laughter. *Nervous laughter* tends to occur when we are aware of an impending threat or danger. There is *slapstick laughter* where we laugh at physically awkward or calamitous body movements of others (or sometimes ourselves). *Sadistic laughter* occurs when we laugh at the misfortunes of our enemies. If our enemy is present, we may direct the response *at* the person as *mocking laughter*. *Surprise laughter* tends to occur when an event (such as a bursting balloon) is completely unexpected. *Social laughter* is the sort of polite or gregarious laughter that signals our participation or desired membership in a particular social group. In social laughter, we may be aware that nothing is particularly funny, but we may still laugh as a way of reducing any social tension. Finally, *humor laughter* is an overt form of pleasurable entertainment, usually relying on some form of joke-telling. Humor does not require laughter (we can find things amusing without laughing). Nor does laughter necessarily indicate humor.

These different forms of laughter would seem to defy any single explanation. What is it that all of these situations share? Why do nervousness, surprise, sadism, slapstick, humor, and social politeness all tend to lead to a characteristic "ha-ha-ha" respiratory reflex? I think that Aristotle already had the answer 2,500 years ago. In his *Poetics*, Aristotle described laughter as "a species of the base or ugly . . . some blunder or ugliness that does not cause pain or disaster."[17]

Aristotle's view was reiterated by the eighteenth-century German philosopher Immanuel Kant when he characterized laughter as arising from "the sudden transformation of a strained expectation into nothing." The key here is the contrast between the fast *reaction response* and the slower *appraisal response*.

The different forms of laughter all share two features: (1) Each situation is tinged with risk or fear, although this fear may arise simply because of a failure to anticipate the future (i.e., surprise). Remember that the reaction response always assumes the worst in surprising situations. (2) However, cognitive reflection either eliminates or inhibits the assessment of fear or risk. In the case of slapstick, the fast reaction response arises from *empathy*—the brain's disposition to "mirror" the psychological experiences of others. For example, research by Tania Singer and her colleagues at University College, London, has shown that similar brain regions are activated when we see someone else experience pain as when we ourselves experience pain.[18] The fast reaction response responds to the physical danger (whether to ourselves or others), but the ensuing cognitive appraisal recasts the apparent danger as inconsequential. The same pattern characterizes *Schadenfreude* when we laugh sadistically at the misfortunes of those we exclude from our social in-group: these are the misfortunes of *others*—not ourselves. Once again, there is a rapid recognition of the existence of harm, followed by an appraisal that we ourselves are not endangered—we might even benefit from the situation. In the case of nervous and social laughter, these rely on a cognitive appraisal that a social superior will not mistreat us, for example.

Consider the simple game of "peek-a-boo." The game is surprisingly resilient. Pediatrician Dr. Robert Marion describes how his sympathy for a distressed infant led to a long game of peek-a-boo: "I covered my face with a hospital towel and pulled that towel away for nearly three hours, to the delighted squeals of this one-year-old."[19] How is it that the sudden appearance of a face can cause such delight? Once again, it is the combination of "innocent surprise." The surprise causes a fast biological alarm, followed by the appraisal that no harm will happen. But how is it possible to sustain such a response for nearly three hours?[20]

There are excellent reasons why the fast-track brain should not lower its guard. The sole purpose of these reaction responses is to defend against those rare circumstances that are truly dangerous. The whole fast-track system is designed to tolerate large numbers of false alarms. Unlike the townsfolk in Aesop's fable, the fast-track pathway tends to respond to the cry "wolf" no matter how many times it occurs. The fast-track system maintains its vigilance. It never grows tired of assuming the worst. If the fast-track system did adapt or habituate to all the false alarms, then the reaction responses would not be available for those rare occasions when they are really needed.

Musical surprises fall almost exclusively into the category of innocuous risks.[21] In generating musical humor, composers are taking advantage of the biology of pessimism. As we have noted, surprise is always a sign of adaptive failure, and so the initial limbic response is necessarily negative. However, the slower appraisal mechanism intercedes and the ensuing contrastive valence results in a broadly pleasant experience.

Laughter's Origin

If laughter is an innate reflex, then laughter must originate as an evolutionary adaptation with its own unique biological history of development. The idea that laughter originated as a type of fear response does not seem to square well with our human experience of humor. Laughing is fun. How is it possible that a species of fear became transmuted into something pleasant? If I might be permitted some evolutionary speculation, I would like to suggest that the development of human laughter might have evolved along the following path:

1. Unvocalized panting occurs in response to surprise. This panting is part of a generalized increase in physiological arousal. Like the gaping mouth of the "surprised" face, panting prepares the animal for action.
2. For highly social animals (like humans and great apes) the biggest dangers come from other members of our species (conspecifics).
3. Threats from other conspecifics also evoke unvocalized panting. The threatening animal recognizes the panting as a successful provoking of a momentary state of fear in the threatened animal. The evoked fear means that the threatened animal has been successfully cowed. Panting becomes a signal of social deference. As an aside here, we might note that dogs exhibit "social panting"—where submissive animals begin panting when a dominant animal (sometimes a human owner) appears.[22]
4. Being able to evoke panting in another animal reassures the dominant animal of its dominant status. Similarly, panting in the presence of another animal serves to communicate one's submissiveness. For the submissive animal, this communication is valuable because it establishes the animal's submissive status without having to engage in fighting.

5. In order to enhance the communication of deference, panting becomes *vocalized*—that is, the vocal cords are activated. Vocalized panting becomes a specific signal of deference or submissiveness.
6. Vocalized panting generalizes to most surprising circumstances.
7. In some primates, "panting-laughter" is reserved specifically for surprise linked to nondangerous outcomes. In highly socialized animals, most dangers are social in origin, so panting-laughter is commonly associated with social interaction.
8. In hominids, panting-laughter becomes explicitly social. Mutual panting-laughter within a group becomes an important signal of reciprocal alliance, social cohesion, and peaceful social relations.
9. The contrast between negative reaction feelings and neutral/positive appraisal feelings evokes an especially pleasant state. Human culture expands on these agreeable feelings through the advent of "humor" as an intentional activity meant simply to evoke laughter.[23]
10. Laughter becomes commonplace in hominid social interaction. In order to reduce the energy cost of laughter, the inhaling–exhaling form is replaced by the more efficient vocalized exhaling (i.e., modern human laughter).

Evolutionary storytelling is fraught with dangers, so the above story should be viewed pretty skeptically. My story is offered only as an illustration of how the innate behavior we call laughter might have evolved from surprise-induced fear. Biology is a complicated business, and most physiological functions develop in strikingly convoluted ways. The actual origin of human laughter is probably much more complicated. But as a universal human reflex, there is no doubt that laughter has an evolutionary history.

Awe—Takes Your Breath Away

Laughter is not the only response that can be evoked by surprise. Imagine that you are making your way through a dense jungle where tangled branches render your progress fitful. The thick vegetation obscures your vision so you can only see a foot or two ahead. Suddenly, you break through a mass of vegetation and find yourself standing immediately on the edge of a high cliff. A few more steps and you would plunge over the precipice. While laughter might be a possible response to this situation, a more likely response is to gasp. A *gasp* is an abrupt inhaling followed by a momentary holding of one's breath.

This imaginary scenario differs from the usual fight-or-flight response. There is no need for an impending expenditure of energy. Instead, the danger is more suited to the often-overlooked *freeze* response. Standing at the cliff's edge, *panting* would serve no useful purpose. But freezing *is* an appropriate response. A single rapid inhale provides a reservoir of oxygen that allows us to hold our breath.

Other situations that might evoke a freeze response are easy to imagine. You might encounter a snake, or a sparking electrical cable, or someone pointing a gun. In Brazil, I once encountered a spider's web the size of my outstretched arms and legs—it stopped me dead in my tracks, and I distinctly recall holding my breath. The enormous web was beautiful—brilliantly illuminated in the sunshine. But it was simultaneously a fearsome sight.

Holding one's breath has several benefits. It reduces movement and sound, which makes it more difficult for a possible predator to see or hear us. Reducing movement and sound also makes it easier for us to listen intently, and to see more clearly. Marksmen are better able to hit the bull's-eye when they stop breathing and shoot between heartbeats. A cricket will merrily chirp away until approached. Then it will become silent until it assumes you have moved away.

The freeze response is most probable when the danger remains fixed. The danger associated with the cliff remains as long as we are near the edge. The danger associated with encountering a snake remains as long as the snake is nearby. Laughter, by contrast, is more likely to occur when an apparent or actual danger rapidly dissolves. The bursting of a balloon represents a momentary rather than sustained danger. I might slip on a staircase, but immediately recover my footing without falling—an event that then results in my laughing. A parent says "boo" to a child, who subsequently erupts in laughter.

In short, laughter is a response to an apparent or momentary danger, whereas the gasp is a response to a sustained danger. Following the gasp, subsequent appraisal of the situation will determine whether the danger is real or "manageable." If the danger is real, then the gasp will be a prelude to sustained fear. If the danger is manageable, then the gasp will be a prelude to *awe*. Wobbling on the edge of a cliff we may experience fear. Standing securely on the edge of a cliff we may experience awe. Being in close proximity to a venomous snake we may experience fear. If the snake is being held by an experienced snake handler then we may experience awe.

Like laughter, the gasp can be vocalized or unvocalized. The unvocalized rapid inhale is the quiet, clandestine form. Silence is an appropriate response to sustained danger. The vocalized "ah!" when we gasp is more unusual, because it is rare for humans to vocalize while inhaling. Vocalizing also makes it more difficult to remain unobserved. But the vocalized form of the gasp is more audible to others and so may have some communicative function. In short, the unvocalized gasp is a self-serving defense response, whereas the vocalized gasp is a more altruistic response that can alert others to potential danger.[24]

As in the case of laughter, the gasp can be evoked by stimuli that at first appear dangerous, but on reflection are recognized as not actually dangerous. That is, the reaction response is acutely negative, but the appraisal response is either neutral or positive. It is this contrast that transforms the experience into something pleasurable.

Accordingly, we might characterize awe as a form of pleasurable surprise, one that mixes a sense of apparent sustained danger with an appraisal that the situation is okay or good. This characterization of awe is reinforced by the word's etymology. In English, the word "awe" traces a circuitous historical path that nicely echoes the combination of positive and negative emotions. My Webster's dictionary reports the archaic meaning of the word "awe" as "the power to inspire dread." The word originates in the Greek *achos*, which means pain. Webster's defines the more modern meaning of "awe" as follows:

> emotion in which dread, veneration, and wonder are variously mingled: as 1: fearful reverence inspired by deity or by something sacred or mysterious 2: submissive and admiring fear inspired by authority or power (he stood in ~ of the king) 3: wondering reverence tinged with fear inspired by the sublime

Standing on the edge of the Grand Canyon is both dangerous and a wonderful opportunity to get a good look around. The sight is surely awesome—it takes your breath away. If God is to be both loved and feared, then meeting God would be a good reason for a person to feel awe.

Frisson—Thrills from Chills

Fear can provoke many different types of physiological reaction. When threatened by another animal, we might prepare to *fight* rather than flee or freeze. In the fight response, the first order of business is to produce an aggressive display. By signaling one's readiness to fight, it is possible that the threatening individual might back down, and so an actual fight can be avoided. Aggressive displays can include the displaying of teeth, making eye contact with the other animal, and generating low-pitched vocalizations. In addition, there are a series of behaviors that are all intended to make the individual appear bigger—and so more intimidating. This includes rearing up (to appear taller) and the bristling of hair (to appear more massive). Cats, by way of example, will arch their backs and make their hair stand on end.

All of these responses are also evident in humans. For example, human aggression can be signaled in the wrinkling of the upper lip, which, if the mouth is open, makes the upper cuspids (or canine teeth) more visible. Although humans are comparatively hairless as mammals go, fear can still cause the hair on the back of your neck to stand on end—a reflex technically known as *piloerection*.

Piloerection also occurs when a person is cold. Shivering causes the skin to tighten and hair follicles to pucker—causing the characteristic "goose flesh" texture. When it is cold, piloerection helps capture a layer of insulating air—a warming technique that works a lot better for animals with more hair than us humans. Even when piloerection occurs in response to fear (rather than cold), we still have a feeling which is often described as "chills." I think that this feeling is another example of the comparatively rare emotions that conform to the James–Lange theory. Recall from chapter 1 that James and Lange argued that the physiological response itself can precede and lead to a characteristic feeling. In chapter 1 we saw an example of such feelings in the Strack pencil task—where making people flex their cheeks (in a smile-like manner) causes them to feel happier. Here "chills" are evoked by piloerection. Fear doesn't make us "cold." Instead, fear causes piloerection, and this response evokes the phenomenal feeling of coldness—a feeling that would be a normal sensation when piloerection is evoked by cold temperatures.

This raises the question of why the linkage is not the other way around. Why is it that when we experience fear, we feel chills, but when we are cold, we don't feel fear? I suspect that the reason for this asymmetry harkens back to the very distant evolutionary past. Piloerection almost certainly arose first as a method of thermoregulation. For animals with lots of hair, making one's hair stand on end is a good response to a cold environment. Later, natural selection "discovered" that piloerection is a welcome addition for creating a convincing aggressive display (a physiological borrowing that biologists call a "preadaptation" or "exaptation"). Once the neural wiring was added so that aggression generated piloerection, the phenomenal sensation of chills simply came along as an artifact.

The phenomenon of "chills running up and down your spine" is technically referred to as *frisson*—a useful loan-word from French. The phenomenon has been variously described, including "thrills," "shivers," "chills," and "goose flesh." Psychophysiologists Gunther Bernatzky and Jaak Panksepp have proposed the memorable term "skin orgasm"—but their term has failed to gain currency.[25] A handful of studies regarding musically evoked frisson have been carried out, including work by Jaak Panksepp, Robert Zatorre, Anne Blood, Richard Gray, Avram Goldstein, and John Sloboda.[26] In chapter 14 we will examine a number of examples of musical passages that evoke frisson. We will see that the frisson response is correlated with two conditions: (1) loud passages, and (2) passages that contain some violation of expectation—such as an abrupt modulation.

Loudness is known to increase physiological arousal. There are good reasons for this connection: loudness is indicative of events in the environment that entail a large expenditure of physical energy. Whether physical energy is embodied in animate agents (such as a herd of elephants) or in inanimate objects (like boulders rolling down a slope), high levels of physical energy are more likely to pose a danger than low levels of energy. There are good reasons for organisms to be highly aroused by loud sounds.

In my own listening experience, I have found that I can reliably manipulate the magnitude of a frisson episode by adjusting the playback volume on my stereo. Louder reproduction enhances the frisson evoked by a musical passage, while quieter reproduction reduces the frisson. Incidentally, I've also observed that frisson is influenced by temperature: I am less likely to experience frisson when I am warm or hot. Cinemas and concert halls with lots of air conditioning might well enhance the emotional experiences of patrons.

Along with loudness, frisson is more likely to occur when there is an unexpected modulation, or an abrupt chromatic mediant chord, or an unexpected onset. In Beethoven's "Ode to Joy," many listeners have pointed to the pleasure evoked by a memorable moment when one of the phrases abruptly begins half a beat early.

As we have already noted, surprise is biologically bad. Both loudness and surprise evoke negatively valenced *reaction* responses. The loudness is symptomatic of high energy with a concomitant potential for physical injury. Surprise is symptomatic of an unpredictable environment. Together, these factors represent the potential for significant biological danger.

As in the case of laughter and awe, the frisson response originates in a reaction response shaped by fear. The fast-track brain responds to the combination of loudness and surprise with its usual pessimistic presumption. At the same time, the slower appraising mind concludes that the musical sounds are entirely safe. Once again, the negatively valenced piloerection response is in stark contrast with the neutral or positively valenced appraisal response. Once again, the magnitude of this contrast amplifies an overall sense of pleasure.

Fight, Flight, and Freeze: The Aesthetics of Pessimism

As noted earlier, physiologists have identified three classic responses to danger: the *fight*, *flight*, and *freeze* responses. The fight response begins with aggressive posturing and threat displays. The flight response is characterized by a quick increase in arousal, including rapid preparatory respiration. The freeze response is characterized by sudden motor immobility, including breath-holding.

My idea should by now be obvious. There is a striking similarity between the fight, flight, and freeze responses, and the experiences of frisson, laughter, and awe. The piloerection characteristic of frisson suggests a kinship with the fight response. The modified panting of laughter suggests a kinship with the flight response.[27] And the rapid inspiration and breath-holding of awe suggest a kinship with the freeze response.

When musicians create sounds that evoke laughter, awe, or frisson, they are, I believe, exploiting the biology of pessimism. The fast-track brain always interprets surprise as bad. The uncertainty attending surprise is sufficient cause to be fearful (at least until the more thorough appraisal process can properly evaluate the situation). Depending on the specific circumstances, that fear is expressed as one of the three primordial behaviors of fight, flight, or freeze.[28]

Because the fast-track brain never lowers its guard, musicians can rely on sounds to evoke pretty much the same response each time the music is heard. If the fast-track brain weren't so pig-headed in its pessimistic interpretation of surprise, then familiar musical works would rapidly lose their power to evoke the emotions of frisson, laughter, or awe. Of course, listening does change with exposure. But the fast-track brain responds primarily based on schematic expectations, and these schema change only with extensive exposure. (I'll have more to say about this in later chapters.)

It might seem odd that the experiences of frisson, laughter, and awe rely on the evocation of fear. But this fear appears and disappears with great rapidity and does not involve conscious awareness. The appraisal response follows quickly on the heels of these reaction responses, and the neutral or positive appraisal quickly extinguishes the initial negative reaction. As listeners, we are left with the contrast in valence between the reaction/prediction and appraisal responses—a favorable contrast that leaves us with the sort of warm glow that contributes significantly to the attractiveness of music. In effect, when music evokes one of these strong emotions, the brain is simply realizing that the situation is very much better than first impressions might suggest. In this regard, music is similar to other forms of pleasurable risk-taking, such as hang gliding, skydiving, riding roller coasters, or eating chili peppers.[29]

The truly remarkable thing is that these powerful emotional responses can be evoked through the innocent medium of mere sounds. Of course, not just any sounds will do. Listeners must be enculturated into specific auditory environments where some events or patterns are more predictable than others. As we will see in the ensuing chapters, it is the learned schemas that provide the templates that enable the fast-track brain to make predictions, and in some cases, to be surprised.

If a musician wishes to evoke the experience of laughter, awe, or frisson, then the musician must be intimately familiar with the normative expectations of ordinary listeners. This is not a novel observation. Music scholars have long noted the importance of *convention* as a basis for generating various emotional responses. For example, in her book, *Haydn's Ingenious Jesting with Art*, musicologist Gretchen Wheelock describes many of the devices and elements in Haydn's music that relate to humor. Wheelock quite rightly emphasizes the necessity of convention to humor. Humor requires surprise; surprise requires an expected outcome; and an expected outcome requires an internalized norm. Composers must activate either normative schemas (such as styles) or commonplace clichés in their listeners if their violations of expectation are to have the desired effect. Leonard Meyer recognized this half a century ago.[30]

In each of laughter, awe, and frisson, an initially negative reactive response has been followed by a neutral or positive appraisal. What about the possible situation where an initially negative reaction response is followed by a *negative* appraisal? That is, what would happen (musically), if fight, flight, or freeze were allowed to be expressed unimpeded? Negative appraisals can arise for all sorts of reasons. A listener might find the style distasteful, regard the work as overvalued, dislike the musicians, or have unhappy past associations. A listener might be disappointed by the content of the lyrics, be embarrassed by the amateurism, be offended by an apparent plagiarism, or be disgusted by crass commercialism. But the sounds themselves will inevitably lead to the conclusion that the stimulus is "just music." Unlike the growling of a bear, the sounds do not represent an imminent danger. There is no need to run, flee, or hide from these sounds.

Of course it is possible to imagine fantastic scenarios where "just music" might be truly terrifying. For example, suppose you had just watched a horror film at the cinema with your friends, and then returned home alone. As you step into your darkened house, music from the horror film comes blaring at you from your stereo. (Perhaps you have inventive friends whose notion of "fun" suggests some need for psychological counseling.) In such a circumstance, most people would genuinely flee. But the ensuing flight would not really be evoked by the music. It would be evoked by the appraisal that either an intruder must be in your home, or that there really are evil spirits out to get you. These are both good reasons to feel genuine fear.

The "just music" assessment might explain why, of laughter, awe, and frisson, it is frisson that is the more common experience for listeners. An organism is most in command of a fearful situation when it chooses to fight, rather than flee or hide. That is, if the fear-inducing situation proves to be manageable, then one would expect an aggression display, rather than gasping or panting. The least fearful reaction response would generate frisson rather than laughter or awe.[31]

When surprised, how does a brain decide whether to initiate a fight, flight, or freeze response? Even though no conscious thought is entailed, some assessment must be involved—however crude the judgment. In general, if the danger is assessed to be relatively mild or manageable, then a fight response should be more likely. If the danger is assessed to be sustained, then the freeze response should be more likely. If the danger is assessed as an intermediate threat, then fleeing might be more likely. Almost certainly, context will play a role. When gathering with friends, for example, surprises are probably more likely to evoke laughter than awe or frisson. When alone in a dark alley, by comparison, the same surprise is not likely to result in laughter.

Interestingly, these same experiences of laughter, frisson, and awe can be evoked by purely intellectual pursuits—as when attempting to solve a problem. For example, consider the intellectual charge or pleasure that we feel when coming to understand, grasp, or solve some problem—an experience that is commonly dubbed the "insight" or "aha" phenomenon. The experience of solving a problem can also evoke laughter, frisson, or awe. But these different responses appear to be linked to distinctive characteristics of the problem-solving experience. For example, laughter is more likely to arise when the solution to a problem is suddenly recognized to be trivial. Frisson is more likely to arise when we make a connection that simplifies a problem. Awe is more likely to arise when we realize that the solution to a problem turns out to be massively complex. That is, frisson accompanies the experience of "gaining command" over a problem. Awe accompanies the experience of "losing command" over a problem. Laughter accompanies the experience of transforming a problem into something trivial.

A task as commonplace as solving a crossword puzzle can be the occasion to experience all three such emotions. We might have individual moments of insight. A chuckle may attend one solution, for example. As we finish the puzzle, we may have a frisson-like experience as we realize a previously unrecognized thematic unity that links the puzzle words together. Turning the page, we might have an awe-like response when we see that the next crossword puzzle is much larger (and harder).

In this chapter I have argued that laughter, frisson, and awe are three flavors of surprise. Since surprise represents a biological failure to anticipate the future, all surprises are initially assessed as threatening or dangerous. The body responds by initiating one of three primordial responses to threat: fight, flight, or freeze. The physiological basis for these responses can be seen in some characteristic behaviors: hair standing up on the back of your neck, shivers running up and down your spine, laughter, gasping, and breath-holding. In most real-world situations, evoking fight, flight, or freezing behaviors will prove to be excessive—an overreaction to innocuous situations. A slower cognitive process ultimately makes this assessment and begins to inhibit or modify the fast reaction response. Although the situation begins with a negatively valenced limbic response, it is replaced by a neutral or even positively valenced limbic response. The contrast between these successive assessments generates a subjective experience akin to relief. What begins as a brief moment of fear is transformed into a strikingly positive phenomenal experience.

In this chapter I have also argued that reaction responses are necessarily conservative or "pessimistic." To maintain their effectiveness, especially in environments that may generate lots of false alarms, reaction responses must be resistant to habituation or extinction. That is, reaction responses should be difficult to "unlearn." Notice, however, that this situation does not preclude learning. That is, there is no theoretical impediment to learning *new* ways of being surprised. In fact, there are significant biological benefits to be gained if an organism is able to learn new ways to become fearful. When it comes to fear, learning should be easy, but unlearning should be difficult.

At the beginning of this chapter I identified a number of types of emotions that can be evoked by music. But the discussion here has considered only three of these emotions: laughter, awe, and frisson. What about some of the other strong emotions that can be evoked by music, such as joy, exuberance, serenity, angst, sadness? Here I need to remind readers that the purpose of this book is to address the phenomenon of expectation (and the emotions that arise from expectation). While expectation probably plays a role in these other emotions, I suspect that the phenomenon of expectation is less relevant in evoking emotions such as sadness or joy.

Reprise

In this chapter, I have introduced the phenomenon of surprise. Expectations that prove to be correct represent successful mental functioning. The experience of surprise means that an organism has failed to accurately anticipate possible future events. From a biological perspective, surprise is always bad—at least initially. I have noted that there are different expressions of surprise and that these expressions echo the primordial behaviors of *fight*, *flight*, and *freeze*. Musical surprises are capable of initiating these responses, but the responses themselves are short-lived because an ensuing appraisal ultimately judges the stimuli as nonthreatening. The appraisal response inhibits the full expression of fight, flight, or freeze and also prevents the individual from becoming consciously aware of their brief brush with fear. Instead, the listener is left with a corresponding response of frisson, laughter, or awe. Evidence in support of this account can be found in the various physiological responses associated with fight, flight, and freeze that can also be observed among music listeners: piloerection, chills, changes of heart rate, laughter, gasping, and breath-holding.

I have suggested that the pleasure associated with these responses arises from limbic contrast—a phenomenon I've called *contrastive valence*. Pleasure is increased when a positive response follows a negative response. While surprise is biologically bad, surprise nevertheless plays a pivotal role in human emotional experience. Surprise acts as an emotional amplifier, and we sometimes intentionally use this amplifier to boost positive emotions. Suppose you had the opportunity to know in advance all of the future times and places when your most cherished goals or ambitions would be fulfilled. I doubt that many people would want such knowledge. Part of the joy of life is the surprise that accompanies achieving certain wishes. When all of the uncertainty is removed, the capacity for pleasure also seems to be diminished.

There is a tired old joke that begins by asking "Why do you keep beating your head against the wall?" Neuroscience gives some credence to the answer: "Because it feels so good when I stop." Of course there are more effective forms of head-banging. Music is one of them.