The cover of this bulletin moves. At www.servinglibrary.org/read.html?id=77066, you should see a single spiral graphic, constantly spinning in a clockwise direction. Relax your mind and stare directly at the spiral's center for 30 seconds. Then click your mouse on the spiral and continue to look at its center. The spinning will stop, but in its place an altogether-stranger motion appears.

I. A TUNE

Take "Peter and the Wolf," for example. Sergei Prokofiev wrote this concise symphony in 1936 after an invitation from the Central Children's Theatre to write a score to cultivate a child's musical tastes and spark her interest in the sonic possibilities of an orchestra. It was a slight commission, and he was already a well-known composer; still, Prokofiev worked furiously over two weeks to write both a story and the music that would propel it. He had two young kids at the time and realized that an adventure story, better yet one with a bit of danger, would hold a child's attention; meanwhile, the music could get on with its hidden agenda.

Every character in "Peter and the Wolf" is represented by a particular instrument and a specific melody. The duck by the oboe, the bird by the flute, the cat by the clarinet, the grandfather by the bassoon, the wolf by three horns, the hunters by the timpani drums, and Peter by the strings. Each time one "appears" in the performance, we identify that character by the sound of their instrument and the shape of its melody. The resulting work wasn't any existing musical form, exactly — it was something like a demonstration piece, or orchestral fairy-tale, where the instruments are the actors and they tell the story by performing it with occasional help from a narrator. We follow the story, and at the same time are taught to identify each of the instruments. In my recording, Boris Karloff is the narrator. He begins:

Early one morning, Peter opened the gate and went out into a big, green meadow ...

Karloff's deep baritone is followed quickly by a string quartet playing Peter's tune, a sequence of 24 notes in a rising swell that embodies what it is to be young, in a meadow and embarking on a grand adventure. Transcribed, the melody looks like this:

As the musical story progresses, more than one character appears at once, and the score uses the specific musical motifs of each to render the

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scene. So at the beginning, when the bird (flute) is sitting high in a tree and Peter (strings) approaches, we hear both characteristic themes in musical conversation with each other. Nether is precisely the same as it was performed when the characters were first introduced, but enough of the whole remains to easily recognize each tune. It goes on like this with increasing complexity throughout the rest of the 33-minute work, until, by the end, as all of the characters parade in a line triumphantly carrying the captured wolf, we can easily discern each animal in the musical picture. Their respective themes play at once, overlapping, combining, and weaving in and out of each other in symphonic counterpoint. Karloff sets it up:

And now imagine the triumphal procession ...

Peter comes first, but this time his theme is slowed to a stately march, transposed to a lower key, and played not only by the strings but joined by the wolf's brass horns. The hunters follow, now played by the oboe and strings. Throughout the composition, each character's melody is subjected to any number of transformations: sped up, slowed down, truncated, played by another instrument, compressed, stretched, essentially altered. The tunes are not the same, but still, we have no problem identifying each.

Why?

Austrian philosopher-psychologist Christian von Ehrenfels asked the same question in 1890: How do we know a melody? What is it that we hold in our head when we carry around a tune? A melody is a sequence of tones arriving as sound waves of various frequency. Our ears collect these vibrations, convert them to electric current and pass them to our brain. These notes are stitched into a particular arrangement of pitch, rhythm, and harmonic relationships. That melody is written into our memory as a tune that we can recall in the future. The precise mechanics of the translation are what bothered Ehrenfels.

Ehrenfels started from physicist Ernst Mach's paper of four years earlier, "Contributions to the Analysis of Sensations." In it, Mach proposed that in addition to the elementary sensations of three straight lines connected one to another, we also directly sense "shape-forms" (e.g., a triangle).

He expanded this idea to "time-forms" as well, and proposed that the perception of melody might work the same way, so that when we hear individual notes, we are also aware of a total shape. But Ehrenfels found an essential contradiction: we can only directly "sense" what is simultaneously present. As we can't see what has already happened, neither can we hear that which has already played. Melody needs time to reveal its sequence.

To make "sense" of a melody, we must rely on our memory of at least the previous few notes. Without this context, Ehrenfels reasoned, every melody that ended on the same pitch would be heard as the same tune. Then, for a run of say 12 tones (or even 24, as in Peter's theme), a few notes remembered each side of the current pitch can't possibly be enough. Instead, we must file a record of the entire melody in our memory. Further, he reasoned, this record is not just the brute-force collection of every individual tone sensation, its exact pitch, harmonic frequency, timbre, and so on, but something considerably more generic and more forgiving. Think about it: when you recall a tune in your head, you remember its overall shape, not its precise tone sensations. How else can it be that "Happy Birthday" inevitably begins on 14 different tones when 14 people start to sing it in unison?

Since we don't store the individual notes of a melody as exact sensory duplicates, there must be something else. Ehrenfels suggested that this is the *relation* between the notes, and that these relations are what is distinctive. They can be spatial (a musical interval), temporal (rhythm), harmonic (timbre), or, more likely, some complex multivariable equation of all of these. For Ehrenfels, a clear solution to the question of why we still recognize a melody when we hear it transposed to another key was that we store information about relations, rather than specific pitches.

But melody is more elastic yet. In Peter's theme, when you hear the rising figure of the first measure repeated (and transposed with a slightly different ending) in the second measure, something strange happens: this second occurance of the musical figure *retroactively* affects your perception of the first, making it stronger, more resonant, more definite. A melody, then, is not simply one fixed, coded set of relationships.

The relations are themselves DYNAMIC and DEPENDENT—they INTERACT. A local change to any one part can shift your perception of the whole thing.

In his paper, Ehrenfels offered rhetorical "proof" that a whole melody is something other than the sum of its musical parts. He describes a scenario in which a melody is played, one note at a time, to each of a group of people. It is then repeated, but this time played in its entirety to one individual. Ehrenfels then asks, is there a difference in understanding the melody between the group who each heard one note, and the individual who heard the whole tune? Clearly. And it follows that the one who heard the whole melody must have received something else in addition to its musical parts. This individual sensed not only the notes, but also a phantom character, which, after Mach, Ehrenfels called the melody's *Gestaltqualitäten* or "Gestalt quality." Gestalt is a German word whose meaning doesn't map neatly onto English. It's used here as a measure of wholeness, coherence, completeness: a set of relations, a particular configuration, a form, a shape, gestalt.

Ehrenfels was only hinting at this quality. How gestalt might structure all kinds of perception outside of melody was left to a next generation led by his student Max Wertheimer. By 1932, years after that research was undertaken and Gestalt psychology was an active concern, Ehrenfels was asked again to "present the doctrine of gestalt qualities in the simplest possible form." From his bed in the weeks before his death, he dictated a crisp three-page primer. It had the same title as his 1890 paper (*Über "Gestaltqualitäten"*) but was $^1/_{12}$ its length. His ideas had cohered over time.

. . .

One hundred years earlier in 1797, Englishman John Heatherington strolled the Strand in central London wearing a strange hat. *The Times* described it as "a tall structure having a shiny lustre and calculated to frighten timid people." It was a top hat, and its alien form caused a proper ruckus among the crowds of central London that day. There was screaming, barking, fainting, and even a young boy breaking his arm in the chaos. Heatherington was collared by a policeman and brought to stand before

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the Lord Mayor for an offense of disturbing the peace. He paid a £500 bond and was released.

The top hat had already existed for a number of years by this time. One account has it invented in southern China around 1775 for a visiting Frenchman. Another suggests that it hails from Florence, and another has it evolved from the English sugarloaf hat. In any case, the first top hats were decidedly elegant — made of fine beaver felt combed with a nitrate-mercury solution used to lock together the coarse hairs in a smooth fabric. The finished hat's finish required consistent preening with a velvet brush.

Construction soon evolved into an industrial process with steam-powered felt manufacture and standardized "scientific" sizing. Materials became more common with silk replacing beaver, followed by hatter's plush. More top hats were made more quickly, sold for less money, and demand grew. By 1850, England's Prince Albert was prominently wearing one, and top hats were standard daytime headwear for a European gentleman. Subtle formal variations arrived, including the Chimneypot, whose sides mirrored the gently curved profiles of rooftop smoke exhausts in industrial London; the Platonically-perfect Stovepipe with its straight vertical cylinder anchored to a flat, circular brim; the acutely concave form of the Wellington; the tapered crown of the Cumberland; and the short, squat and eminently practical hat of the yeoman farmer. Top hats came in a range of heights from the John Bull's 5 $^{3}/_{4}$" to the supreme vertical statement of the Kite High Dandy at 7 $^{3}/_{8}$". A collapsible model, or Opera Hat, promised a more portable version easier to store in now-crowded hat check rooms.

When French realist Édouard Manet painted a typical scene from 19th-century Parisian nightlife in *A Bar at the Folies-Bergère*, top hats were everywhere. The gentleman reflected in the foreground ordering a drink wears one. The hundred or so other men that can be seen in the large mirror hanging behind the bar do as well. In the dim light and reduced detail of the painting's background, the top hat is still easily identified. Manet renders the hats with supreme economy, some in as little as two concise brush strokes — one up and one across. The hat's essential form is unmistakable.

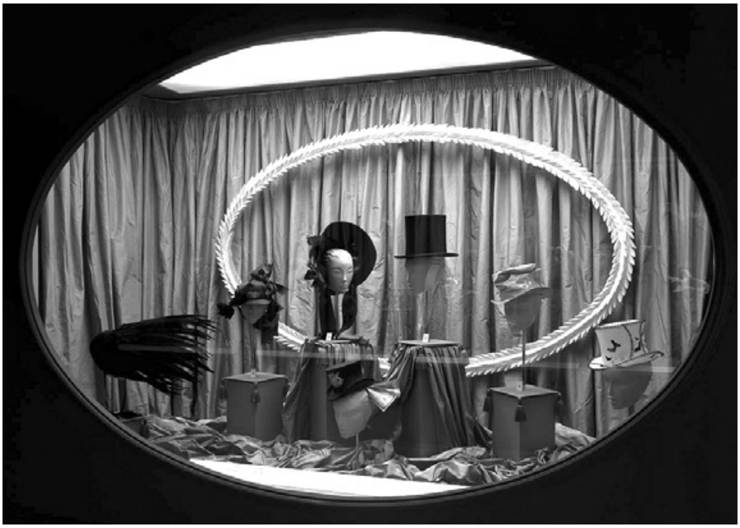
Édouard Manet, *Un bar aux Folies Bergère*, 1882, Oil on canvas, 96 × 130 cm (37.8 × 51.2 in.), with detail

By 1860, the president of the United States also wore a top hat. At 6'-4", Abraham Lincoln chose to exaggerate his stature with an austere Stovepipe, and the hat amplified his public image as a forthright and principled man. He wore it consistently, from the White House to the Civil War battlefield, and stories suggest that Lincoln even pushed it into use, storing important papers in the negative space of its vertical cavity. He wore a top hat to Ford's Theater the night he was assassinated.

By the time I saw "Hats: An Anthology" at the Peabody Essex Museum in Salem, Massachusetts this past Christmas, the top hat had all but disappeared completely. It was something from *Bugs Bunny*, a historical photograph, a magic show, or a Grateful Dead concert parking lot. And, since these cartoon versions of the hat were all I knew, I had never given the form much thought.

The exhibition was comprised of a sequence of inset display cases each containing about ten hats. The contents of each were completely mixed—an elegant feathered headpiece from 1924 was staged next to a woolly toboggan from 1982 emblazoned with the Green Bay Packers logo, next to a black, felted wool ten-gallon saloon from 1851. A crowd formed around the case that featured Darth Vader's original head helmet from 1977. Jacquelyn Onassis's pillbox also commanded attention, though it sat next to another, tackier, model baldly emblazoned with the Union Jack. The cases continued like this, each containing hats of a jumbled chronology, with mixed socioeconomic registers and divergent forms. It was fantastic.

One display case in particular caught my eye. Working clockwise from center front, it included a squat Chimney Pot, a face-covering bonnet of pheasant feathers, a black “Merry Widow” mourning cap, a plain velvet and silk day hat, a rumpled pink satin and silk number from Comme des Garçons, and a stitched cardboard form. In the dead center of the constellation was the top hat, a “Prince Albert,” circa 1850. The hat’s form struck a deep chord inside me.



Confronted with this perfect example from the mid-19th century, I felt as if I could discern *within this one hat* all the variations of form that existed backwards and forwards in time. The hat in front of me buzzed, its profile actively shifting from an austere Stovepipe to a concave Chimney Pot to the Cumberland’s tapered peak. Its rise moved up and down, the lilting brim curled and released. It was as if I’d always known the various top hat shapes, and this particularly resolved model triggered what had been latent in me. I have no better word to describe the experience than “moving.”

In his studies on melody, Christian von Ehrenfels identified two distinct gestalts—spatial and temporal. Spatial gestalts are the overall characteristic of a form perceived simultaneously with its parts. For example, the “squareness” of a square in addition to its four straight lines or, in a sonic register, the cluster of a musical chord we hear from its individual notes. Temporal gestalts are a fuzzier flavor, like the shape of a melody we sense in addition to its notes, or the continuous pure motion we feel when shown a series of sequenced frames. If, as Ehrenfels asserted, there IS an extra quality to a melody not produced by simply summing its tones,

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and, further, if we store melody not as raw sense data but as a set of coherent relations, and (most radically), if melody has a form disjointed in time that can be known at once then, might not the immediate sensation of a whole separated in time also be stored in a discrete object? A top hat, perhaps?

II. AFTER EFFECTS

It went like this: On vacation in the autumn of 1910, traveling by train through southern Germany, psychologist Max Wertheimer was struck by a railroad crossing sign. The sequence of lights on the sign "moved," lighting one-by-one along a definite path like the lights surrounding a theater marquee. As a psychologist already invested in perception, he asked himself, why do we see movement when the individual light-bulbs remain stationary? They are simply lit one at a time, in a definite sequence, and somehow this translates into the concrete sensation of continuous movement. Is it an illusion? Are we being fooled, or do we actually perceive motion itself, directly?

Wertheimer aborted his Rhineland holiday, disembarked in Frankfurt, and headed to a toy store. He bought a zoetrope and set it up in his hotel room to begin to answer these questions. The zoetrope, or "wheel of life," is a proto-movie projector which produces a sensation of continuous movement from a sequence of discrete frames. A typical model might have contained, for example, around 16 drawings of a horse trotting, which were arranged in counterclockwise sequence around a strip of paper lining the inside of a cylinder. The exterior would have an equal number of vertical slits cut into the perimeter. If one were to spin the zoetrope and peer through one of these vertical openings, the discrete stills would magically come to life as one drawing after the next would appear, producing the continuously moving image of a trotting horse. Wertheimer replaced the strip of drawings with a considerably simpler pattern of discrete, straight lines. He drew one 3 cm horizontal line at the beginning of the strip and a second such horizontal line in the middle of it, about 2 cm lower in the frame. As the wheel turned slowly, one line appeared, then the other in obvious succession. If the zoetrope spun very rapidly, the two lines would appear at once, one above the other. But at an intermediate

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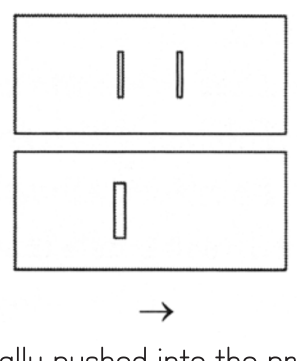
speed, one would see motion—a horizontal line moving up and down continuously.

The experiments soon outgrew his hotel room. Wertheimer telephoned the Frankfurt Academy of Social and Commercial Sciences, a well-funded and progressive research institution. Wolfgang Köhler answered the call—he studied physics, wrote a dissertation around aural perception in Berlin, and had just arrived at the Academy to work as an assistant. Wertheimer described his research agenda. Köhler must have been sympathetic, as he arranged space and resources for Wertheimer to continue his research. Another young psychologist, Kurt Koffka had just shown up too. The three men clicked, and, as Koffka described, "had the same enthusiasms [music, for one], saw each other daily and began discussing everything under the sun." Wertheimer, Köhler and Koffka worked closely together in Frankfurt over the next several years, and then in overlapping configurations for the rest of their lives, to establish the firm conceptual ground of Gestalt psychology. At the Academy, Koffka and Köhler acted as the principal subjects in Wertheimer's experiments on perceived, or "apparent" motion.

Experiments were set up in multiple configurations. The simplest ingeniously repurposed a magic lantern slide projector. Wertheimer replaced the typical glass transparency with a thin metal sheet in the middle of which a 3 x 7 cm vertical rectangle had been cut. To the fixed face of the slide feeding tray, he attached a cardboard sheet with two vertical apertures placed about 2 cm apart.



When the tray was manually pushed into the projector's beam, the cardboard cutouts remained fixed while the metal slide moved. Light escaped only when the opening on the metal slide aligned with either

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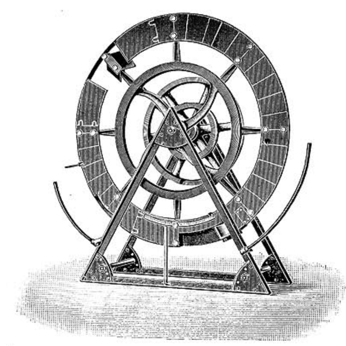
opening in the fixed cardboard gate. This ensured that the lantern's projections would appear discretely, at different points in the subject's field of vision, and that the time between these appearances could be controlled. Wertheimer described:

Moving the slider rhythmically back and forth, one soon finds an appropriate timing ... at which the observer sees not two stationary projector images, but a single line that *moves* from one place to the other.

As with the zoetrope, Wertheimer used this arrangement to produce apparent motion. Producing real motion was only a matter of removing the cardboard with its two fixed openings, then moving the metal slide's single slit back and forth across the light source.

Wertheimer had access to more sophisticated apparatuses at the Academy, including a tachistoscope. Where the zoetrope was configured like a salad spinner, and the magic lantern's slides slid horizontally, the tachistiscope was oriented vertically, like a wagon wheel. Its large rotating ring with periodic and precisely adjustable apertures along the perimeter was used to modulate a light source from behind, so as to project an image sequence through a viewing lens directly to a subject's eyes.



Using this arrangement, Wertheimer could modulate the sizes and the shapes of images, and even present real and apparent movement stimuli simultaneously. Crucially, the tachistoscope allowed for precise and consistent control of the times between exposures.

When the same figure is shown in two discrete positions sequentially, the time between the two events determines what the subject perceives. If this interval is very small, then the two events appear simultaneous. If it is much larger, the figures succeed each other as two discrete perceptual events. But when the length of the interval is between these two poles, one continuous motion is seen. In extensive tachistoscope experiments, Wertheimer reported remarkably consistent responses with simultaneity appearing at 30 milliseconds (σ) between exposures, succession at 200 σ, and motion, more or less strong, in the grey zone between these limits. Optimal motion was identified at around 60 σ. After two years of work, Wertheimer published his results in *Zeitschrift für Psychologie* as "Experimental Studies on Seeing Motion." This 1912 paper firmly marked the birth of the Gestalt school although it scarcely used the word. It begins:

One sees motion: an object has moved from one location to another.

Wertheimer tagged motion as a perceptual given, something we see just as surely as an apple or a can of beans. And his investigation was timely. Motion pictures ("movies") had just arrived, and others were already trying to understand how a stroboscopic flash produces the sensation of movement from a series of distinct frames. Competing theories attributed motion to a perceptual illusion produced in the brain, a fused compound of visual residues, a mechanical mistake involving eye movements, an illusory judgment, or simply a perceptual anomaly. Wertheimer recognized it as something considerably stranger.

At exposure intervals just north of 60 σ, something surprising starts to happen: the figure disappears, but the motion remains. Subjects reported seeing movement, but were unable to say anything about the object that was apparently moving. Wertheimer named this pure, disembodied movement by the Greek letter phi (ϕ). The ϕ phenomenon, or object-less motion, was "simply a process, a transition," and its nature was explicitly dynamic — "an across in itself."

The final step for Wertheimer in proving the ϕ phenomemon and his claim that we directly sense motion was the equation of apparent with real movement. He used a well-documented effect that appears after viewing a consistently moving object. When the motion stops, a strong sensation of movement in the opposite direction to the original is seen. Aristotle gets credit for first describing this phenomenon: after staring for a while at the

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downward flow of a waterfall, he shifted his gaze to a rock on the shore. The rock then magically appeared to move upwards. If real and apparent motion were perceptually equivalent as Wertheimer suggested, then, he reasoned, the same aftereffect should follow when viewing continuous apparent motion. He provided a convincing demonstration using a spiral like this:

When this static graphic is set in motion, the spinning form produces a distinct sensation of inward movement, or tightening of the spiral coil. It appears to be constantly growing smaller. The size and shape of the spiral does not change, of course. This contracting movement sensation is a pure ϕ phenomenon.

Given the figure's asymmetry, as the spiral rotates, its lines occupy a series of positions that do not align. The lines *appear* to move from the outside of the figure to the inside although the spiral merely spins in a circle. The effect is so pronounced that it trumps the actual movement of the spinning graphic. In place of a rotating disc, we see a pulsing figure constantly swirling down a cosmic drain.

Even more remarkable, when the spiral is stopped and the contracting apparent motion ceases, a negative aftereffect is produced PRECISELY as with unidirectional real motion. The static spiral viscerally appears to expand, producing the ϕ phenomenon's mirrored döppleganger. It is positively trippy.

The spiral confirmed what Wertheimer had already seen with the zoetrope, the magic lantern, and the tachistoscope. In those experiments, subjects were consistently unable to distinguish between real and apparent motion, and when asked to identify the stronger sensation, they more often chose the apparent. Although the spiral actually spins, this real movement produces no substantial aftereffect. Instead, it is overridden by the expanding counter-motion that arises from the phantom (ϕ) sensation of continuous inward movement. This spiral experiment proved that there is no sensible difference between real motion and apparent motion. Apparent motion is a perceptual fact.

The consequences of this equivalence were profound. Köhler recalled the stakes concisely almost 50 years later in the first of four lectures at Princeton University called "The Task of Gestalt Psychology":

If apparent movement is perceptually real, then it clearly proves that, when local sensations occur in different places under certain temporal conditions, the corresponding visual processes are by no means independent local facts; rather, these processes INTERACT, and thus the traditional axiom that they must be independent facts has to be discarded.

Movement, like melody, is a perceptually dynamic whole. But Wertheimer made a distinction from what his teacher, Christian von Ehrenfels, said about melody several years earlier. Ehrenfels suggested that a tune consists of both the individual sensations of the tones as well as an additional quality, a kind of spectral glue (or gestalt quality) that binds them together to form a coherent whole melody. Wertheimer inverted the operation, more or less dispensing with the independent sensations altogether. With Köhler and Koffka, he made the radical assertion that WHOLES COME FIRST, and any discrete sensations — parts — appear only by working backward. We see the world principally in sets of dynamically interacting relations, wholes, gestalts.

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Wertheimer went further yet, applying this model continuously across different time scales. Koffka described this in a 1931 lecture:

He joined the movement experience, the movement phi, to the psychology of pure simultaneity and pure succession, the first corresponding to form or shape, the second to rhythm, melody, etc. ... now at last form had become a subject that could be handled.

Recalling the motion experiments: What we see is a function of the time between impressions. If the gap is small, the two become one simultaneous object. If it's large, then one follows the other and is legible as a process. In-between, we see motion. Wertheimer had outlined a perceptual continuum between shape and melody, objects and processes. Translated to a simple diagram, it looks like this:

SHAPE ⟵⟶ MELODY

MOTION

In Frankfurt, Wertheimer, Köhler and Koffka produced a flurry of research in the years following the motion studies. Wertheimer moved on to static forms, and showed why the brain perceives whole arrangements first, and how various configurations produce stronger or weaker gestalts. He demonstrated that, like motion, static graphic forms also rely on perceptually dynamic relationships in which a change in one part has a corresponding effect on the whole. Köhler applied Gestalt to his ongoing research in hearing and aural sensation. In experiments aimed at discerning the individual notes that form a musical chord, Köhler found that his subjects heard tones that were not physically present, and he explained this through the perceptual primacy of gestalt wholes. And Koffka synthesized perhaps the most radical position of the three, suggesting that gestalts were not limited to our perceptual sphere, but extended to motor acts as well. For him, dashing off a sketch was not merely a sequence of mechanical mark-making, nor was playing a melody only producing a series of tones, but rather these physical acts were organized whole processes in themselves.

Koffka left Frankfurt in 1912 to teach in Giessen, and Köhler departed in 1913 for the Canary Islands to study chimpanzees. The three men

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reunited in Germany by 1920, when Köhler was offered a position at the Psychological Institute in the University of Berlin. Köhler soon succeeded Carl Stumpf as its director and invited Wertheimer to the Institute. Koffka remained in close contact while teaching in Frankfurt. The Institute was set up on two floors of Berlin's abandoned Stadtschloss (Imperial Palace), a grand space with high ceilings and an open floorplan to accommodate ambitious experiments.

Gestalt psychology was by now an established school of thought. It had a home in a deluxe facility, a trio of charismatic figures directing its research program, and even its own academic publishing organ. Wertheimer, Köhler, and Koffka established *Psychologische Forschung* in 1921 as the journal of Gestalt psychology. Its most important papers were published here, including Wertheimer's from 1923, "Investigation on Gestalt Principles," colloquially called "the dot essay" for its consistent mingling of the text with dot graphics used to carry its central argument.

After ten plus years of productive work in Berlin, the political situation in Germany made it impossible for the three to continue. Each soon left for America. Wertheimer landed at the New School for Social Research in New York, where he arranged a position for Köhler. Koffka began teaching at Cornell. Koffka and Wertheimer died early, and Köhler was left to carry the Gestalt banner. Gestalt theories came under increasing intellectual scrutiny for being merely descriptive, rather than predictive or explanatory. Gestalt psychology soon fell out of intellectual fashion as behaviorist and other schools took hold.

Perhaps it was inevitable. Gestalt's theory of knowledge fell in direct epistemological contradiction to the broader protocols of science. Deeply coded in the DNA of scientific positivism is a fundamental belief that the world is composed of so many individual facts, and by rigorous examination of these, stacking one understanding on top of the other, the towering edifice of scientific knowledge is constructed. Gestalt insists on a less linear approach—any part or fact has meaning only in the way that it fits into an existing whole theoretical structure. Gestalt replaces science's postivism with the equally firm conviction that what is true today may not be true tomorrow. A newly uncovered fact will shuffle the entire arrangement soon enough.

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After the fact, too often Gestalt psychology has been summarized lazily by the folk wisdom that "The whole is greater than the sum of its parts." But that's precisely wrong — for the Gestaltists, the whole is not GREATER THAN, it is DIFFERENT FROM, the sum of its parts. In fact, there may be no meaningful parts to speak of, only a persistent regression of overlapping wholes. As Jan Zwicky recently observed: "It's gestalts all the way down."

Prior to his paper on apparent motion, Wertheimer published "Numbers and Numerical Concepts in Primitive Peoples." In it, he identified an alternate use of numbers, which resisted any absolute reference to countable parts. He offered the example of a builder in search of wood for a house. The builder could count all the pieces required, construct a mental shopping list, and find the needed items. Alternately, he could construct an image of the whole house in his head—a dynamic model, including all the cuts of wood, plus all the relations between them. He could then interrogate the model and fetch the pieces that fit together. Wertheimer called this mental whole the *Gruppenbild* or "group image." He argued that it was considerably more powerful than counting, and provided a distinctly fluid concept of number. Extrapolating from the "primitive" people he studied, Wertheimer claimed that we see and count objects not absolutely, but rather IN RELATION TO functional units (wholes), and these cannot always be divided into discrete, countable members. The whole simply isn't equal to the sum of its parts. He offers another case:

I break a stick in two. One approach says, I now have "two." (Two what? That's immaterial, I have two—new—units.) The arithmetic makes a jump: first there is one, a stick, then there are two ... and between the first and the second state of affairs there is a gap, which is ignored.

This example foreshadows Wertheimer's later motion experiments. The gap here between the stick's two states corresponds to the time interval between two impressions that determines whether we perceive one simultaneous form or two discrete objects. Inside these two limits, there is only motion—pure change. This stick's whole transformation and its constituent parts, which don't add up properly, hint at the rickety arithmetic and impossible set theory underneath any particular gestalt.

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III. INFINITE VERSIONING

But we'll call a stick a stick. Better yet, let's call it one stick then two, not forgetting that "one" and "two" are words and therefore merely point to external concepts. It doesn't help much using the digits "1" and "2" instead — they're symbols, too. They stand in for something else. That something is the concept of number. In the simplest case, it might be described as a measure of quantity, but in fact, it is a good deal weirder. We are used to how words shift; they're context-sensitive, subjective, essentially relative, and they "mean" by marking their proximity and distance to other words. But numbers are supposed to be definite, absolute, eternal. We grow up learning that numbers aren't like words at all. Max Wertheimer, for one, knew this assumption was wrong: numbers can be relative, as well, and parts don't always sum neatly to wholes. He was well-acquainted with the mathematical-philosophical inquiry into the essence of number published in 1893 by German mathematician Richard Dedekind. Dedekind intuited that numbers are not tied concretely to measurable magnitude. He lays out his thesis in his preface to "The Nature and Meaning of Numbers":

Numbers are the free creations of the human mind; they serve as a means of apprehending more easily and more sharply the *difference* of things.

He continues by describing number as a consequence of the "ability of the mind to relate things to things." Dedekind hinged his argument on Naïve Set Theory, which his friend and colleague Georg Cantor was developing around the same time. Set theory is the root-level logic of mathematics, sitting below basic arithmetic, number, even counting. Fundamentally, set theory concerns the study of groups of things, or sets and their members. For example, a set of fruit can be described with the members {apple, orange, banana, mango}, or {car, truck, bicycle, horse} constitutes a set of vehicles. To define number rigorously, Dedekind asked what property these two sets share. If you pair each fruit with a specific vehicle in a one-to-one relation, and this pairing exhausts both sets so that every member of the first goes with a member of the second, then what they "share" is their "number." In this case, it's 4.

Dedekind's invocation of number seems to be the wrong way around. He suggests (well, proves) that counting is not an innate reflex, and numbers

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don't identify immutable qualities. Numbers are not handed down from the astral plane, but are instead *produced* by the similarities and differences between sets. In this way, a number can be identified concisely as marking a *relation* between two things, or two sets of things.

Set theory abstracts these relations even further. It's a logical lasagna wherein sets may include other sets or even themselves. Two sets are considered equal if they have the same members. Although numbers arise from the correspondences of sets, it's possible and quite useful to have sets of numbers also. The infinite collection of positive whole integers (called the natural numbers) is one such set. Its members are listed as $\{1,2,3 \ldots \infty\}$. The set of irrational numbers, or those that cannot be described as a fraction of two whole numbers, is another. These two sets, the naturals and the irrationals, hint at how strange and stretchy the concept of number actually is. For example, the "number" of members in the set of naturals is ∞. Remove one member from the set, like "1," and the number of members remains ∞. As for the irrationals, none of its members can even be described precisely by existing digits. The best we can do is approximate their values using an infinite string of decimals or assign a symbol to stand for that "number." π is a prime example. Other irrationals live in anonymity, without proper names of their own.

Two sets are called "similar" if one can be changed into the other continuously using the same method. It's easiest to understand by using sets of whole numbers. So, the sets $\{1,2,3,4\}$ and $\{1,4,9,16\}$ are said to be similar because every member of the first set can be transformed into every member of the second set by multiplying itself by itself. $1 \times 1 = 1$, $2 \times 2 = 4$ and so on. Dedekind identified these transformations from one set to the next by the Greek letter phi (ϕ), just as Wertheimer later would.

If we follow this logic, we could say that the set of fruit {apple, orange, banana, mango} is similar to the set of vehicles {car, truck, bicycle, horse} if, and only if, the same magic fairy dust that turns an apple into a car (ϕ(apple) = car) also turns a mango into a horse, or a banana into a bicycle for that matter. It seems unlikely, so the two aren't similar.

Returning to the broken stick, a way out of the arithmetical conundrum appears. Instead of remaining fixed on counting discrete objects, we can

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think instead in terms of *transformations.* In place of one stick, a gap, and then two, we have the same material of one stick transformed into two different configurations. Gestalt psychology insists on such dynamically interrelated and rearrangeable wholes. Instead of objects, we can think of moments or states.

Consider Microsoft Word's "track changes" command. This software function allows you to see immediately where, how, and when a text has been changed, and it attempts to make all the various moments in the life of the file visible. Or how about Apple's Time Machine? The system-level function makes a consistent backup of your computer's files at regular intervals. Entering the Time Machine interface allows you to magically roll back the clock and reset a specific file to a previously saved version, while leaving the rest of your computer in its present state. Wikipedia's recent changes can be easily compared to the current version from the sidebar menu. A software "diff" tool makes it crystal clear what has changed and what has not by comparing multiple versions and highlighting the differences between them. Web browsers retain your history of recently visited sites, and a page accessed today may be different from the same page tomorrow. There is even a meta-"track changes" for the whole Internet called the Wayback Machine. Type a URL into the search field at web.archive.org and the Wayback Machine recalls snapshots of the that website at regular intervals stretching back to 1996. Click on a particular date, and you're transported to that page, then. Hyperlinks work both within the site and outside of it, allowing you to surf the 1996 web in 2013 on a 2012 MacBook Air running Safari v 6.0.3.

Tracking versions becomes considerably more complicated when making software instead of using it. Active software products are a work-in-progress, under constant revision. Each product release contains both additional features and new bugs. The bugs get fixed, a new version is released, and the process rolls on. Most software follows a versioning scheme that uses three numbers separated by periods, such as OS X 10.8.3. The first is used to identify a major change, the second a minor improvement, and the third to mark a slight revision. Other versioning schemes have come and gone, such as adding the year to the product name in Adobe Illustrator 88 or Microsoft Windows 95. Donald Knuth's TeX versions successive releases by adding one further digit in the infinite sequence of a decimal approximation of π. Knuth says the software, currently in v 3.1415926, dies with him. The project will be frozen, and the version number changed from the current string of approximate digits to its purely irrational symbol.

Versioning becomes hairier yet when writing code. A commercial software project involves a potentially large team that is not necessarily working in the same room or even at the same time. The development process is logistically baroque, and also modular. Modern programming languages are built on an object-oriented model in which chunks of code are treated as black boxes that can be developed individually, plugged into a larger framework, revised separately, and repurposed. Software engineering lacks the linear clarity of an assembly line — its workflows are knotty and opaque. Small changes in one part of the code can have large effects elsewhere in the project, so keeping track of who wrote what, when is mission critical. Version Control Systems (VCS) are fit to the task, and allow a large group to work on shared files simultaneously without stepping on each other's toes or rewriting their functions. An early version control system named Source Code Control System (SCCS) appeared in 1972 at Bell Labs. It was updated and replaced by an alphabet soup of protocols including RCS (1982), CVS (1986), CVSNT (1998), and SVN (2000). The fact that these were so quickly outdated themselves highlights the thorniness of the problem as software projects continued to grow larger and more distributed. By the time Finnish programmer Linus Torvalds issued this veiled invitation in 1991:

I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) ...

to launch what would become the Linux operating system, projects had grown beyond all reasonable capacity to corral the complexity of their development process. Linux is an open source project built from hundreds of thousands of contributions by volunteer coders coordinated through an online codebase. The current release is v 3.8.8. It contains more than 12 million lines of code spread across 36,000 discrete files. As the project scaled, Torvalds became frustrated with the existing version control softwares, so he wrote a new one from scratch in 2005 called Git.

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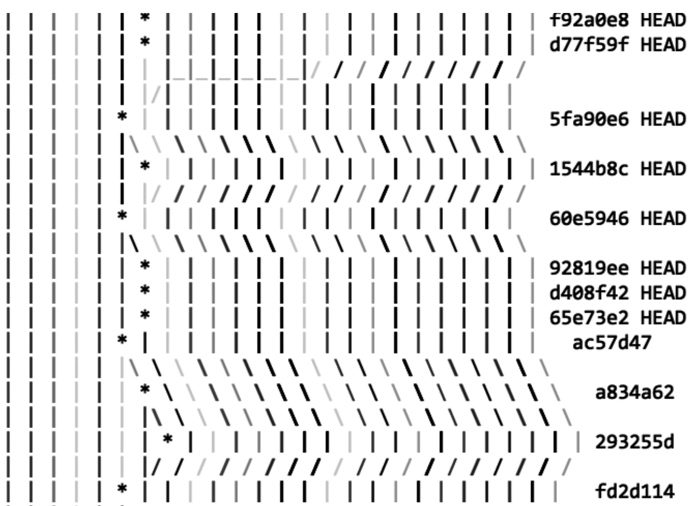
Git has been quickly and widely adopted, in part, because it's an explicitly *distributed* version control system. Rather than one central repository (typically stored on a server) that holds the master project files, Git works with any number of linked repositories. Each instance of the code, each repository, is equivalent, and there is no "master." Instead, Git identifies the master as A COMPLEX SET OF VERSIONED RELATIONS among the individual copies. The software brokers the required transactions to keep each copy up-to-date using commands like push, pull, clone, branch, merge, and commit. Repositories can also be stored online at sites like Github.com, a repository of repositories, which become massive, publicly-shared code warehouses. Unlike previous version control systems, Git doesn't track the history of any particular file, but instead monitors all of the raw project data (regardless of which files it is written into), making snapshots of what the whole looks like at any specific time. This is perhaps the most radically powerful part of Git's model, as it doesn't track changes, it monitors transformations. Scrolling back to a previous version is simple — comparing snapshots is done via the diff command, and a graph, drawn as a tree with branches, commits and merges, which makes it possible to see what has changed and what has stayed the same.



Swiss product designer Max Bill addressed versioning 50 years before in his essay "Continuity and Change." Bill was writing about hardware not software, but the terms are familiar. He marked out continuity as that which persists and change as that which mutates. He limited the domain of these terms to a particular product category: "We judge a chair, for example, not only in terms of its individual qualities but also as a representation of its type—chairs as a whole over a longer time-span." Bill was a Gestaltist, to be sure. He was well-aware of Wertheimer and crew's work and applied this framework to design. For Bill, good gestalt embodied the harmonious, stable arrangement of a product's relations. These included not only the specific form choices made in designing, say, a watch, but also the relation between a specific watch and the entire category of "watches." Good gestalt yields the most "typical," valid form, completely in accord with its type. However, he acknowledged that it was not nearly so simple, and pointed to Viennese architect Adolf Loos's thoughts on top hats from "Regarding Economy" from 1924:

A top hat can take a variety of forms. Imagine a row of a hundred of them. I want to go to a funeral. I try various shapes and see that most of them are impossible, ridiculous, and that only one hat fits. The 1924 hat, let's say. This hat is the only possible one for me and the time in which I live.

Loos writes off this counter-example to fashion and proceeds in his appeal, saying, "I reject any form of innovation-mania." In the next paragraph, he continues, "We should measure beauty in terms of time." Loos advocated an incremental and eternal approach for design, but still he recognized that a form, like the 1924 top hat, might be valid only at one particular moment. He didn't, however, allow for a less linear accounting. Time is not so straight. (Just look at the overlapping versions and tangled branches of a Git project graph.) Any form and its judgment at a specific moment is valid for that time ONLY. Its standing may be changed retroactively in the future: A new form appears, affecting the whole class and each member's standing within it, effectively re-centering the category. Bill suggested morphology, the study of form over time, would be the best tool to understand this versioning process.

Morphological studies can be carried out empirically and visually, but there is an even more definite flavor: mathematical morphology is a formalized language for identifying transformations over time. Its mother-tongue is set theory. Mathematical morphology studies whole groups and their shifting relations to understand how any one form changes in time.

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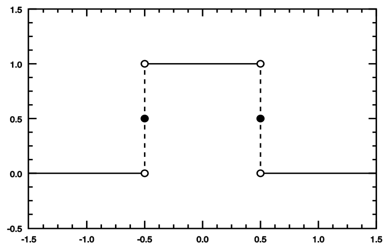
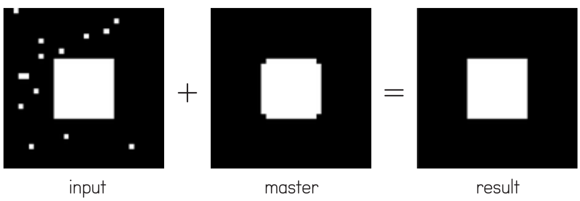
A typical application is digital image processing, and, as luck would have it, includes a method called the Top Hat Transform. The shape of the function graphs a line that resembles its name:



Applied to the two-dimensional grid of a greyscale image, the function compares its pixel values to a bounding structure, a "master" of sorts. The Top Hat Transform draws out areas of similarity and areas of difference and produces one composite image that shows what has changed and what has not. It may be applied across an unlimited set of images at once, revealing how their forms relate. You can think of it as Git's diff command set to work on images.



Version control is useful for hardware (products) and essential for software. But what if the thing that is changing is neither one nor the other? With the recent appearance of 3-D printing, "real" objects can be made directly from digital data. The technology is becoming cheaper and more widespread, resulting in an expanding community of things that are neither hard nor soft, exactly. These are mongrels, whose forms are constituted of the relations between the data that define them and when and how they were produced. Make one small adjustment to the computer model, hit "print," and you have a new form. As the source material is digital, to morph between any two particular instances is computationally direct, and also continuous. It's no giant leap to imagine that the two-dimensional Top Hat Transform might be expanded to address morphological changes in 3-D-printed objects over time. We might be able to visualize instantly

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the entire geometric history of a certain form. A specific path through time can be programmatically collected, assembled into a model, and printed to produce, say, a fourth-dimensional teacup with all its forms and times embedded. Alternately, we can imagine a time-lapse model that would trace the teacup's evolution.

But it's unlikely that we really need such technological hijinks. Maybe we would be better off developing slower eyes. This was Gestalt's pipe dream — a new vision that would allow us to see whole shapes in longer exposures assembled over time. It's the top hat that's *also* a tune.

Max Wertheimer pointed to its outlines in his motion studies when he identified the ϕ phenomenon. This sensation of pure, object-less movement, a transformation in itself, marks the demilitarized zone between things and processes. Here, objects are usefully suspended, appearing as integrally related sets of transformations rather than any single, resolved composition. Identifying and defending the existence of this phantom ϕ, and asserting that we sense this movement directly, led to charges that the Gestaltists were mystics or magicians. Perhaps they were, and performing an old trick: the one in which a live rabbit is pulled from the static, negative void of an ordinary top hat.

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Apparent motion experiment in process at the Psychological Institute, University of Berlin, c. 1920