Assembling Movement:  
Scientific Motion Analysis and Studio Animation Practice

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[F]or animators—those microscopists of the cinema—the substitution of images contains the very fabric of their art, just as, for biologists, the behavior of cells contains the secrets of living organisms.

—Alexandre Alexeieff, 1970

In employing an organic analogy in this account of his work, animator Alexandre Alexeieff echoes a long tradition of linking animation to the study of life. Animation, as one frequently reads in popular criticism, is an art form that plays with the boundaries of life: constructing an illusion of a living world or creating an alternate fantasy life, imbuing inert objects with a vital spirit, or composing abstract forms that dance about like intentional beings. However, Alexeieff’s definition goes beyond these familiar tropes and suggests something much more concrete about the relationship between animation and biology. Just as a biologist dissects organic bodies to understand the inner workings of life, an animator probes into the essence of cinema by dissecting moving images. Or, in a more provocative formulation, animators are not
just filmmakers; they are also scientists of film. This claim isn’t a self-aggrandizing gesture (at least, it isn’t only that) but instead is a statement about the particular skills required to animate an image. Animation challenges the filmmaker to synthesize movement where there is none, frame by frame, by orchestrating a “substitution of images.” Or, as Alexeieff notes in another passage, whereas photographic live-action cinema begins by breaking down and stilling real movement, “[a]nimated movement is not re-constituted by projection: it is created on the screen for the first time.” As such, animation requires a certain level of close, methodical inquiry into the fundamental rules of motion, whether that means studying the trajectories of moving bodies or more intangible dynamic processes, such as emotions or musical rhythms.

The emphasis on understanding the workings of movement explains why Alexeieff’s analogy does not just point to science in general but also turns to the life sciences in particular. After all, by the twentieth century, the study of organic life also became inseparable from the close study of movement, from the concrete behaviors of discrete organic particles to the more abstract forces (reproduction, synthesis, evolution) that propel biological events. Since many of these dynamic processes cannot be optically seen or captured in a single still image, modern life sciences also took interest in the moving image as a device for capturing and analyzing movement.

Alexeieff’s poetic description of the animator as a biologist of cinema is thus indicative of a much wider historical and conceptual relationship between animation and scientific inquiry. Broadly, I would characterize this relationship as a shared interest in studying and visually rendering movement with the aid of moving-image technology. For early animators and for modern life scientists, the cinematograph was an instrument of motion analysis in advance of (and often in preparation for) serving as an instrument of movement documentation. While early twentieth-century biologists and industrial researchers of motion relied on the cinematograph to disassemble organic and mechanical processes into discrete instances or manageable cells, early animators, working in reverse, used the cinematograph to reassemble movement from discrete poses or images (building toward the celluloid “cels” in classic drawn animation).

This shared interest fostered a relationship of mutual influence in how the different fields approached their study and visual rendering of movement. The life sciences, as a number of scholars note in this journal issue, have frequently relied on animated figures
and images in order to model complex biochemical interactions and communicate the invisible structure of organic processes. However, early animators, as I propose below, also drew influence (directly or indirectly) from techniques developed by the life sciences in order to visually compose and communicate movement. This connection was particularly evident in early American studio animation methods and training guides, which form the focus of this essay. Whereas many experimental animators took up the language of scientific inquiry as a more symbolic call to dedicate themselves to the study of movement, in early studio animation, scientific motion analysis became both a literal and rhetorical model for the production of moving images.

The first part of this essay outlines organizational affinities between the study of movement in scientific motion analysis and the manufacture of movement in early animation studios, using Walt Disney Studios as an exemplary case. Walt Disney Studios not only adopted an industrial assembly system for producing films but also turned industrial studies of bodily movement into a systematic method for structuring and composing animated sequences. The second part of this essay describes a number of common aesthetic conventions that scientific studies of movement and early animated films employed in arranging moving objects and bodies in space. These common conventions cannot be easily attributed to direct influence but instead point to broader underlying assumptions about the structure of living motion—specifically, its modularity, cyclicity, and seriality. Driving the development of motion-capture techniques in both the life sciences and in studio animation was their shared interest in mining the movements of specific bodies (specimens, models, characters) for encrypted signs of some kind of essential or archetypal patterns. The pursuit of such embedded universal patterns, as the final section notes, led to a coincident transition away from tracking movement through series of discrete instances and toward the development of abstracted linear movement notation strategies.

The methodological and aesthetic affinities between early studio animation and early motion analysis persist in the contemporary relationship between computer animation and scientific imaging practices. From various motion-capture devices, employed in bioengineering labs and computer-generated imagery (CGI) animation effects alike, to computer software designed to synthesize dynamic processes in virtual 3-D, the life sciences and the commercial animation industry continue to share similar technologies and aesthetic strategies for modeling and rendering movement. By locating and examining earlier iterations of such shared techniques...
and conventions, we can begin to understand these otherwise widely distinct disciplinary trajectories as adjacent branches in a common modern history of motion visualization.

**Movement Segmentation and Assembly**

The cinematographic apparatus served two critical functions in the advancement of modern scientific motion analysis. First, the camera’s rapid sampling of images could capture movements that would otherwise escape even a most diligent observer, such as a high-velocity event or a micromovement. Conversely, staggered snapshots of a very slow event could be combined to create a sped-up portrait of a longer cosmic or organic process. By analyzing visual recordings of movement, a scientist could note the finer nuances of a complex kinetic system and could revisit an event that would otherwise only be accessible to imperfect memory. Second and equally important, the cinematograph fixed the fleeting and temporal nature of movement into static serial objects, such as a photographic sequence or a film strip, that could be tangibly assessed. The experimental potential of using rapid photography to spatially entrap the ephemeral quality of motion was enthusiastically championed by Étienne-Jules Marey: “shortly before [movement] flew, and now, a prisoner, it reveals itself the rules that govern it. It can be understood!” With the cinematograph and other early moving image rendering devices, movement could be arrested into series of instances; those instances could then be segmented into temporal and spatial coordinates, archived, and analyzed.

In some ways, the cinematograph as a scientific instrument defined its science by providing a visual model in which movement could be disassembled and reassembled into constituent components: limbs and joints, spatial positions, instances. Philosopher Henri Bergson therefore argued that the cinematograph, as both a technology and an epistemological model, embodied an instrumental and utilitarian approach to movement. The cinematograph turned movement into a discontinuous, malleable, and manageable property. Not surprisingly, the favorite subject of motion analysis was the modern assembly line—its impact on bodies operating or passing through its sequential stages. Although early scientific inquiries into animal and human locomotion were not explicitly rooted in industrial interests, research findings were most frequently applied to industries invested in managing movements of
labor and machinery: the factory, the office, the military, and even the film industry.

While early industrial motion analysis privileged the assembly-line mechanism of the modern factory, early animation studios adapted that mechanism into a system for producing moving images. Walt Disney Studios, as the largest of its kind by the late 1930s, employed hundreds of people in an assembly line of film manufacture. Character artists developed and designed cartoon figures, background and layout artists composed the layered mise-en-scène of each scene, animators worked out the actual gestures and rhythms in a sequence, assistants rendered many of the necessary drawings, and then each draft of a moving sequence needed to be cleaned up, inked, painted, prepared for recording, and captured on camera by a range of other departments. This assembly process of building movement occurred not only by dividing each moving sequence into consecutive stages of production but also by dividing each shot into numerous drawn frames and then dividing each frame into constituent layers. Whereas an independent animator might need years to complete a short film, a ten-minute film could be produced in a matter of weeks at the Disney studio. Perhaps this is why the journal *American Psychology* credited its first bibliography on industrial motion analysis to an author allegedly employed by “Walt Disney Productions,” while an early book on motion picture production referred to the studio as a “cartoon factory” and a “cartooning laboratory.” At the Disney cartoon factory, animated sequences could be completed at an unprecedented rate, but the logistics demanded a complex choreography of departments and laborers.

In addition to the challenge of coordinating multiple departments, the very process of drawn animation depended on manufacturing hundreds of drawings per every minute of film. Even the most fundamental element of classical cel animation—the drawn line—was a gesture that needed to be taught and repeated by a collective of artists. To this end, even a single moving sequence had to be divided into stages: animators planning and roughly sketching the most important poses or turning points of a gesture (the essential “keyframes”), assistant animators filling in some of the intermediary keyframes, junior assistants completing all of the required drawings (the “in-betweens”), and finally a range of “cleanup” employees turning the sequences into fully rendered images with uniform bold lines. In order to establish the studio’s uniform look and signature style, the studio studied and then implemented precise labor guidelines for even the smallest of gestures, especially
the gestures of workers responsible for final cleanup and rendering of the images.11

Considering the immense volume of drawings or objects that make up every single minute of an animated film, as well as the numerous gestures that go into every drawing and frame, the decision of how much effort and detail to invest in each animated image frequently became a question of energy conservation. Thinking about movement as a phenomenon generated twenty-four times a second introduced a new dimension of kinetic energy into the cinematograph—the energy of creative corporeal labor. Movement was a currency with which one paid for the dynamic life on the screen—hours of drawing the frames at the animation stand, mere seconds flickering by in the movie theater. Therefore, as Edwin Lutz wrote in his early guide to animation, an animator needed to develop “an economy of labor in getting as much action with the use of as few drawings as possible.”12 This economy balanced between the time of production and the time of projection, or the movement within the frame and the movement it took to produce that frame.

Conserving too much effort by cutting down the amount of drawn frames and the detail of the drawings ran the risk of not getting enough “action,” making the film too inanimate.13 Conversely, making too many drawings or investing too much energy into a frame could become a form of unnecessary expenditure. The idea that a moving image can have just enough movement or that filmmaking can become a form of kinetic waste is an industrial economy of motion that is especially important in the animation industry. It is also a key historical model for the contemporary balancing act in CGI cinema between motion sampling, computer simulation, and manual generation of movement. The particular qualities of movement or level of “action” needed for any project is what determines how much costly detailed frame-by-frame animation is required versus how much can be patterned on prerecorded or machine-calculated movements. Contemporary CGI animated films and video game environments owe their increased visual verisimilitude in large part to concerted industry efforts to better automate the process of animation so that the same images or movement patterns can be replicated and arranged in new combinations more rapidly. This automation of movement is not new to computer production; it was already embedded in the structure of studio animation and the economic demands of mass-producing drawn frames. From the early days of the animation industry, the final look and style of an animated film has always been partly framed as a kinetic
conversion of labor movement into cinematographic movement. As Robert Field writes in his early book on the Disney studio,

This is apparent the moment one realizes that perhaps hundreds of artists are to be employed on the same figure, all having to conform to rigid formulas and required to work under a time schedule. The possibility of inconsistency must be discarded at the outset; the greatest economy of line must be insisted upon to save both time and energy. This opens up the problem of what is and is not animatable.14

The question of how one would animate was therefore also a question of balance between detail and omission, of finding the limits of a desired movement’s visible expression. As Robert Field’s quote explicitly asks, what is or is not “animatable”? Here, scientific and industrial studies of motion became not only models for organizing cartoon production but also invaluable reference guides for achieving a collective consistency of gestural movement.

One of the earliest guides to animation, Edwin G. Lutz’s book *Animated Cartoons*, is an illustrative example of the link between scientific motion analysis and the study of movement in studio animation. Even though the book’s author made a career as a cartoonist before his foray into animation, he strongly connects cartoon filmmaking to scientific inquiry, noting that “to become skilled in animating involves a thoughtful and analytic inquiry into the subject [of movement].”15 The most important animation skill emphasized in the book is not a sense of comedic timing or a creative imagination but rather the ability to break down movement into constituent components. To this end, Lutz argues that animators owe a debt to early scientific “efforts in solving animal movements by the aid of photography.”16 Many animation sequences included in *Animated Cartoons* were patterned directly on Eadweard Muybridge’s photographic studies of movement, which were described as “a great help in comprehending the nature of movement and grasping the character of the attitudes of active figures.”17 Lutz incorporated several of these studies into his guide, some as direct reproductions and others as drawn versions of familiar sequences: the galloping horse, the horse and rider, an elephant, a dog, and a bird (figure 1). Other sequence examples are patterned more on Marey’s chronophotographic studies, including marching soldiers and moving bodies reduced to skeletal limbs.

First published in 1920 in Britain, Lutz’s book was a widely circulated text for decades, since few other practical guides were developed and disseminated among competing studios. The book
would become an influential guide for American studio animators, and subsequent editions even included the promotional tagline “The book used by Walt Disney & other animation pioneers.” Even if the actual examples provided in the book were limited and simple in visual detail, the underlying model of breaking down movement into phases and cycles was crucial to how motion sequences could be taught and standardized across large teams of artists. Phased cycles of motion could be economically adapted for animation, and they could also be more efficiently cataloged in a collective archive of animated samples. Once the movement of a particular cycle was standardized for animation purposes, it could be taught to larger teams of animators, repeated, and readapted for various effects. Animators working in the studio system during the so-called early golden age of animation (1930s–1960s) considered their work to be more advanced and even more evolved than work by their predecessors. However, the central reason for the improvement was not technological advancement, enlarged labor force, or even the introductions of cinema sound and color. Instead, it was the expanding archive of figures of motion—a broadening horizon of what was possible, what could be animated and how.18

Figure 1. Example of an instructional animation cycle from Edwin Lutz’s 1920 book Animated Cartoons. Discrete poses of the horse’s trot are patterned on successive outlines of a Muybridge motion analysis series.
In addition to referencing scientific motion studies, it was common practice for animation studios to record original source footage for productions and to study frame-by-frame footage of live-action films. Fleischer Studios, one of the largest animation studios in the 1920s–1930s, recorded its own footage of moving characters, which was then traced into animated drawings. Studio founder Max Fleischer invented and patented the rotoscope—a technical system for tracing over photographed images—so that a sequence could rely on the underlying movement of a live-action sequence for greater visual realism and production efficiency. The rotoscope was later widely used by many other animation studios, and the technique can be considered an antecedent model for contemporary digital tracing and motion-capture technology. It was Walt Disney Studios, however, that took the study of movement as a central methodological concern. The studio not only maintained its own archive of recorded movements but also organized research trips to study natural dynamics (bodies, plants, environments) and installed mirrors at every animation table so that animators could study their own physiognomy for the purpose of modeling faces.

By the mid-1930s, the Disney studio formally organized a series of mandatory classes in which animators would analyze, study, and occasionally perform figures of motion. Although the classes initially began as informal gatherings among a few animators, Walt Disney supported their development into a full program, eventually turning them into a mandatory curriculum. In these classes, the animators would study moving figures and moving images, slowing down the projector and watching the succession of limbs and angles through a frame-by-frame analysis of the footage.

The Disney animation training program, best known as “action-analysis” classes, influenced a wide range of studio animation practices, especially as many animators moved on to other studios in the United States and abroad. Some of the earliest action-analysis classes were recorded during the studio’s production of *Snow White and the Seven Dwarfs* in the late 1930s. While the studio was working on its first feature-length animated film, the analytical approach to decomposing movement into constituent standardized components became a guiding principle for producing moving images. As Walt Disney wrote to class instructor Donald Graham in a famous 1935 memo, “I am convinced that there is a scientific approach to this business” and that the action-analysis classes could “show the men ways of visualizing action in their minds, breaking the action so that the men are prepared in advance to begin animation of the action and know thoroughly what they are going to animate.” For beginning animators, anatomy classes were greatly encouraged,
while Muybridge’s photographic studies of human and animal locomotion were considered essential reference material. Disney’s rhetoric about a “scientific” approach to the business of animation was also picked up in training and expository literature of the period. For example, the 1939 book *How They Make a Motion Picture* notes that

> Artists and animators must be students of physical and animal anatomy for they must reproduce life-like postures of birds and beasts in almost every conceivable position. Very often they engage models to pose for them—but they do not draft from the living model. A regular motion picture is filmed, showing the subject going through the action: a dance step, an acrobatics or some similar but unfamiliar action which the animators wish to reproduce. This motion picture is then used as a guide to perfect them in the anatomical movements of the dance or acrobatic trick.\(^{22}\)

However, the author mistakenly implies that the studio’s reliance on anatomy classes and recordings reflected an interest in directly “reproducing” lifelike movement. Recorded motion studies were never used for directly copying photographed bodies; in fact, the movement was rarely if ever directly traced. Instead, film sequences functioned as a kind of visible archive or database that could be accessed, should a particular movement problem require a solution.

The idea that animators can pose movement problems and work out movement solutions would come to play an important role in animation discourse over the next century, manifesting itself in concerted efforts to “solve” complex stochastic movements (e.g., obsession with working out the movement of fabric and hair) to more abstract formal experiments (e.g., experimenting with the minimal elements needed to produce movement in depth and through color). Scientific documentations of movement were only one of many reference sources for identifying and resolving animation problems. But their accompanying ideals of “grasping the character” of movement, as noted by Edwin Lutz in his early guide, framed how animators would come to define their work and paved the way for the introduction of movement algorithms in computer animation.

**Poses, Layers, Cycles: Portraying Movement in Space**

Early scientific and industrial motion analysis was not only an influential framework for mass-manufacturing moving images but was also an aesthetic model for portraying movement. The aesthetic
connections can already be discerned in the above example from Edwin Lutz’s *Animated Cartoons*. Like most of the Eadweard Muybridge photographic studies that the book clearly emulates, the cartoon cycles are almost invariably in profile, with characters moving sideways in a succession of poses that flatten the depth and length of traversed space. Although some of Muybridge’s published series included head-on views of moving subjects, none were selected to model animation principles. Where examples in *Animated Cartoons* do deviate from familiar Muybridge plates, they recall the long-exposure images of marching bodies found in Marey’s chronophotographic studies. In the latter examples, the various stages of a gesture are connected and condensed into a single wide frame rather than spread into different discrete frames. However, in both types of examples the predominance of profile views, the flattening of depth, and the reliance on discrete poses of a single gesture all work together to represent movement as a series of changing relationships between parts of a body and a two-dimensional canvas. For example, a walk is shown as a redistribution of limbs and a series of shifting angles. Like scientific motion analysis plates, each animation cycle always contains a starting position, a concluding position that returns closely to the starting position, and important (key) frames that show significant peaks or transitional points in the arc of a gesture.

This approach to fixing, containing, and analyzing movement was particularly convenient for studio animation in three ways. First, the representation of a moving body as an interrelationship of movable limbs and joints was well suited for constructing animated puppets and for economic decisions about which limbs of a figure could stay relatively immobile in successive cartoon drawings. Since profile recordings of a body moving across a flattened background revealed the most marked changes in limb distribution, in comparison to the fairly uniform shapes and subtle changes indicated by an advancing figure, profile views were central to the arrangement of action in early animation. Characters and objects in early cartoons tend to move horizontally across the width of the frame and only rarely advance toward the screen and the camera. During movement, character heads are frequently kept in profile or three-quarter view, and the bodies are segmented so that only the most visually dynamic limbs (swinging arms and pacing legs) are changed and animated between the frames; the remaining portions of the body are simply retraced or rephotographed across the frames without any drawn changes.

The still image in figure 2, from the early Disney cartoon *The Merry Dwarfs* (1929, part of the *Silly Symphonies* series), is exemplary
of how action and movement was arranged across a horizontal plane and with predominantly profile angles. In addition to keeping a profile or three-quarter view for almost all character poses in the film, all character bodies are disassembled so that some segments (e.g., legs and beard tips) are exaggerated in their movements, whereas others (e.g., torsos and faces) are kept relatively static and uniform across the frame. Many animation studios, especially studios working in the so-called limited animation style, developed and maintained similar techniques of animating using stripped-down recurring patterns. The Hanna-Barbera studio, for example, included a stock archive of gestures, such as eye blinks and leg thrusts, that could be rapidly combined and assembled into full character gestures—an archive of stock movements that digital computer software would facilitate decades later.23

Second, photographic motion studies separated the moving body from the background, allowing for the two to be moved at different rates. Scientific and industrial motion studies suspended the body in a carefully structured grid-like space, often with the inclusion of an actual grid in the background, in order to maintain stable reference coordinates that could facilitate comparative analysis across various instances. Against the uniform and rigidly delineated substrate, the moving body appeared at once in

Figure 2. Still frame from Walt Disney Studios’ Merry Dwarfs (1929). Movement is arranged horizontally using recurring cycles.
constant motion and perpetually stuck in place—trapped for analysis. For animators, this process of fixing the body into a stable geometrical grid extended the mechanical principles of Renaissance perspective to the temporal dimension, already anticipating the geometric coordinate system of computer animation. Space was at once potentially infinitely traversable and yet more easily flattened and defined. More important, the relationship between a moving object and its surrounding or defining environment was unlinked. Figure and background were not mutually dependent—one could take precedence over the other.

An animated sequence built on the same principles could therefore keep the background static or could move the background at a different rate than the foreground object. Space could become a container of movement with its own potential rates of change and motion. Within this container moving characters can be easily duplicated and cloned, producing a multiplicity of figures from one primary sample, while the single background supporting the numerous clones combines them into the illusion of a unified environment. Moving sequences based on cloned multitudes, from flocks of geese to cabaret lines of dancing creatures, can be produced by repeating the same movement cycle numerous times against a single aggregating background.

The image from The Merry Dwarfs (see figure 2) once again demonstrates how this strategy could facilitate a complex moving-image system based on relatively simple motion cycles. The dwarfs are animated on one plane, their legs kicking and bending in ways that might suggest they are hopping in place. Additionally, the dwarfs are designed from nearly identical components, such as thrusting legs and bobbing hats, so that they could act as clones of one another. Even if animators did not reuse the same drawings for each dwarf, the kinds of gestures that are required to outline each dwarf are nearly identical and therefore easily repeated. The background, however, is animated on a different plane and moved sideways at its own pace, generating the optical effect of dwarfs prancing forward across a landscape rather than simply jerking and thrusting their legs in one place. Occasionally the entire image is reframed with a tighter or more distant view of the scene, and these reframing cuts are used as an occasion to reset the background cycle, giving the effect of a much more expansive uninterrupted space. The upper half of the background is painted with a busy pattern that provides both horizontal and vertical position markers, forming a stylized version of a grid for establishing spatial reference. The lower half of the background is kept relatively bare so that the character limbs and any painted shadows can distinguish
the bodies from their containing space. Combined together, the moving backdrop grid and the foreground figures create a single moving system within which the characters appear as an advancing multitude within a single environment.24

Third, photographic motion studies represented the movement of living beings as phases of a recurring cycle, a set of repeating gestures that could be extended indefinitely, visually framing the organism as a prospective perpetual motor. The gallop cycle of each horse, or even the individual gallop cycles of the same horse, could have internal unique variations; however, photographic studies mined the movement of individual samples for some underlying pattern that could be practically applied as a universal case. Even when early photographic studies were followed by cinematographic studies, such as those organized by Frederick Taylor or conducted by Frank and Lillian Gilbreth, the filmed footage similarly analyzed repeating workflow patterns for the appearance of a single normative cycle that drove specific individual variations. For animation, thinking about movement in terms of repeating cycles turned characters into modular and interchangeable motion machines. Instead of animating a walking character by drawing alternating leg thrusts twenty times, one could draw a single cycle and repeat it twenty times. The complexity and variation within a sequence would occur by recombining different cycles or by slightly shifting the phase of a single cycle. For example, a single photographic motion plate of a running cat, consisting of twelve distinct poses, offered twelve potential coexisting phases—twelve cats moving through the same cycle but staggered a frame apart to create a differentiating effect.

In *The Merry Dwarfs* cartoon, each of the dwarfs looks slightly different because each character’s moving components are phased at different rates. A simple turn of the head from a three-quarter grin to a profile smile is staggered so that no more than two or three of the characters are repeating the same frame at the same time. Bobbing hats and wobbling beards are similarly redistributed across the different characters so that the aggregate moving system includes internal variation. Ultimately, only the musical instruments introduce the most significant changes among the characters. Using such a modular assembly system for producing movement, animators could therefore insert a high degree of variability and complexity into a moving image by calculating the central “animatable” components and combining those components at different points of space and time. Although this essay focuses on character animation within the studio system, a similar model for producing complexity from sampled elements was crucial to
the compositional aesthetics of many independent and experimental animators as well.25

Animators’ acquired knowledge of how movement appeared to the human eye and how one could simulate it with the aid of the camera was applied to lend what Disney called “factual” weight to the animated image. By producing movement through segmentation of limb poses, a layered system of foregrounds and backgrounds, and recurring phased cycles of motion, early animation shared an analytical approach to movement that aligned it with the aesthetics of early scientific motion visualization. In early scientific motion studies, the separation of figure from ground made it easier to analyze and quantify the body’s internal dynamic workings. The figure was of primary interest, and the background was a stable box for measuring positions over time. In the early animation studio process, this separation allowed for further interplay between figure and ground, and it could also make room for multiple coexistent layers that joined together into a larger system of moving parts. In Walt Disney Studios, the development of the multiplane animation method in the 1930s ultimately standardized this model of visually animating movement as a combined function of layered changes in flat space (movement along the surface of a frame or across a single layer of drawings) and changes in depth (movement across a layered stack of coexisting drawings).

**Lines of Activity: Notating Movement in Time**

Although photographed and filmed motion studies were integral to the history of animation, the goal of analyzing movement was to learn its basic underlying dynamics, not to perfectly reproduce naturalistic movement from recordings. As Walt Disney stressed in his memo to animation instructor Donald Graham, “The point must be made clear to the men that our study of the actual is not so that we may be able to accomplish the actual, but so that we may have a basis upon which to go into the fantastic, the unreal, the imaginative—and yet to let it have a foundation of fact.”26 Animators were encouraged to discover principles of movement so they could use those principles to produce fantastical or imaginary events with a believable weight of “real” observed motion. A prancing man could become a clown, a dancing girl could be animated as a princess, and the gestures of a moving human could be adapted for movements of an animal character or a puppet.

For this reason, directly copying filmed footage or tracing photographed outlines of figures was often restrictive and
counterproductive for animators. The recorded image dictated a certain perspective (the angle of the camera), a certain rate of transition (the rhythm of the actor), and distribution of limbs. Any deviation from the surface details of a recorded movement was frequently more complicated than drawing that movement without any external aid. In order to transform naturalistic movement into more malleable animated movement, to play with pacing and temporal elasticity of the image, an animator needed to break away from the two-dimensional image prescribed by the recorded footage and envision the eventual animated sequence. Walter Stanchfield, one of Don Graham’s successors in the Disney animation training program, writes the following description in his own curriculum for aspiring animators:

Occasionally a bit of live action film is used as source material for animation. Since it is impossible to find actors who are constructed like the cartoon characters, the animator has to extract the essence of the action from the film or Photostat and transfer that to the drawings. It takes a kind of “double-vision”—you are looking at the live action but you are seeing the cartoon character.27

The animator’s capacity for “double-vision” extracts the motion pattern of a photographic sequence and uses it as a connecting medium between two completely different types of objects. In other words, animators directly observed and recorded movements, looking for underlying patterns of motion, in much the same way as observers of scientific motion studies. However, if scientific and industrial motion studies searched for the most exemplary or efficient patterns of movement in order to compare one body to another or one occupation’s gestures to another’s, then animators had to go one step further and manipulate the uncovered patterns by greatly exaggerating them into cartoon figures or by translating them from living to inanimate bodies. For instance, a gesture of someone kneeling down and prostrating the arms in a welcoming bow may need to be translated from a human body to an object (e.g., a broom or a candelabra) with a significantly altered shape yet still maintain its recognizable gestural qualities as a welcoming bow. As such, the type of indexicality that interested animators in the photographic sequence was the appearance of identifiable, believable movement, not some faithful impression of a concrete body. Yet petrified in a sequence of poses or a grid of Cartesian coordinates, photographic motion studies were like an extremely complicated set of instructions for the most basic actions, producing infinitely divisible steps for gestures that almost anybody could
perform in seconds. Motion analysis restricted the diversity of animatable subjects to filmed subjects and did not address the question of which details were necessary to the appearance of movement or which details could be omitted by the animator. In this balance between animated detail and omission, the most essential detail—the object’s individual style of moving and its trajectory—inevitably remained hidden in the variation between the images.28

By the 1930s, Disney studio animators were already noting the limitations of copying live-action footage, repeating stock movement cycles, and animating through the so-called pose-to-pose approach.29 The database system of using the same familiar poses and basic cycles was extremely effective and efficient, but aesthetically it still lacked a certain elasticity and fluidity of movement. Animator Eric Larson described the limitations of precalculated pose-to-pose animation in this way: “It was like stretching a strand of barbed wire tightly between two posts—it didn’t ‘give.’ It exhibited a certain tight, mechanical feeling, with everything being moved the same distance at the same time, with no concern for looseness, overlap, or follow-through.”30 In one action-analysis class during the production of *Snow White and the Seven Dwarfs*, one of the lead animators, Bill Tytla, noted that this rigidity and invariability became apparent whenever animators needed to differentiate between the movements of characters with similar appearances: “[A]nimators have memorized a good stock walk or a stock run, and probably a single stock way of doing everything to be done. This is evident in cartoons where all the characters, regardless of type or personality, walk, run, move the same way.”31 Tytla may as well have been describing the studio’s own earlier work, such as the cloned and repetitive movements of all of the dwarfs in *The Merry Dwarfs*.

Whether or not such mechanical effects had their own aesthetic appeal, they were unsatisfactory for a studio that increasingly pushed for character development and sophisticated, expressive movement. Therefore, in the second half of the 1930s the studio began to emphasize the importance of the animator’s ability to understand the underlying internal forces driving movement—emotion, cognition, directed intent—in advance of learning how to break down and draw discrete gestural poses. As Donald Crafton notes, Walt Disney’s Silly Symphony cartoon *The Merry Dwarfs* and the studio’s feature film *Snow White and the Seven Dwarfs*, released less than a decade apart, look like they were made by completely different studios.32 If in *The Merry Dwarf* the titular characters all move and march in synchronized unison, repeating identical gesture cycles, in *Snow White* the dwarfs are endowed with more distinct outlines, behavioral rhythms, and patterns of movement.
My analysis of animation methods in this period indicates that the studio’s interest in animating more fluid and expressive motion was accompanied by a shift in how movement was planned, visualized, and rendered. The studio’s action-analysis classes called this a shift from “animating forms” to “animating forces.” The “animation of forms” created moving figures by taking an existing outline of a figure or a shape and moving it in increments across a screen—like the sequential stages of a motion analysis study. Conversely, in the “animation of forces,” animators sought and notated the underlying palpable forces that were moving or propelling characters. The new notation took on a dual form: lines of action and lines of activity. In any single pose of a character, the pose would be notated through a rough line of action, a loosely drawn line that indicated the overall tension of the body and only hinted at the eventual positioning of the limbs. The line of action borrowed from rapid sketching techniques in art pedagogy, in which a character’s outline and pose were determined by an overall distribution of central weight. However, since in animation movement was built through small increments of variation over time, one needed to also indicate how the movement of the line would progress across the frames. Here, a second type of drawn line dictated the overall trajectory of movement—what I call the line of activity.

Clear examples of the line of action and the line of activity can be found in two exercise charts from Preston Blair’s seminal animation reference guide (figure 3). In the upper row of images, an animated figure’s skeleton and his eventual corporeal outlines are built around numerous embedded lines of action that transition from more bent arc shapes toward the vertical windup. However, the overall principle of change that underpins the different lines of action in the upper row of images is a kind of straightening-out of the curve. The poses move from a more horizontal stretching of the action to an upright and tense stance preparing for the pitch. To illustrate such a change of the body’s energy over time and to communicate it to a team of fellow employees, studio animators would frequently sketch out a second line, the line of activity, which would traverse the different frames and help guide the various lines of action. The bottom rows of figures illustrate one version of a line of activity, which appears as a dotted curved line that varies its phase and amplitude from row to row. The line of activity could introduce different movements and attitudes into an otherwise identical body—an upright bounce for a confident strut or a swooping downturn for a dejected slump. The line of activity roughly indicates the trajectory of the moving shape over time and also allows for a subsequent decision of where and how many
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Individual poses to actually render. In later animation software this would sometimes be called the motion guide, through which the animator could indicate the particular path of an object that would later be filled by any potential number of frames.

Figure 3. Two extracts from Preston Blair’s 1946 animation guide Advanced Animation. The upper set of images illustrate what animators term the “line of action.” The bottom set of images demonstrate the introduction of what I term the “line of activity.” Reprinted courtesy of the Preston Blair Estate.
During the production of *Snow White and the Seven Dwarfs*, lead animators were thus encouraged to abandon defined contours of figures in favor of lines of action and lines of activity. In action-analysis classes, Donald Graham writes that in the making of the roughs, it is possible to symbolize those forces with very few lines (provided, of course that the animator has a first-rate cleanup man who understands these symbols), so that instead of actually drawing shapes, the animator may indicate the forces involved, and his assistant can then follow up with the forms.

In other words, the main task of the animator was not to render detailed key frames of sequential poses but rather to indicate the underlying trajectory of a gesture by using the line as a kind of movement-notation system. The lines of action and activity would become the primary task of the animator, with the actual rendering to be interpreted and completed by so-called below-the-line labor (low-paid staff, eventually equipped with or replaced by computer software). The animated line became a visual language for representing a diverse array of organic and inorganic processes. As Walter Stanchfied argued, “Line is not just a tracing tool—it is a living, organic thing, capable of describing just about anything you can dream up.” Eric Larson similarly noted that a line could have expressive properties that could evoke rhythm, movement, weight, balance, and attitude. By privileging movement and energy over an outlined shape, the drawn line could exceed familiar and recognizable images and could instead evoke a greater range of kinetic and emotional expressivity.

The studio’s shift away from traced outlines of moving bodies toward notating underlying forces of motion may seem like a departure from the conventions and techniques developed by scientific motion analysis. However, the studio’s transition in fact mirrored and replayed a similar shift that occurred in scientific and industrial approaches to rendering movement. This transition was characterized by waning enthusiasm for mechanical and behaviorist models of bodily movement as well as a gradual return to a more encompassing psychodynamic approach. Like studio animators, industrial motion analysts gradually came to pay as much attention to the underlying psychologies of movement and internal forces propelling the body as to any external actions and effects that it produced. It is my contention that in coming to emphasize distinct character psychology and developing a more fluid, linear notation system of portraying movement, animation studios weren’t trading scientific and industrial modes of visualization for some kind of
romantic expressionism but instead were changing alongside the disciplines that influenced animators from the start. By considering the reasons why studio animators found serial motion-capture techniques insufficient for fully comprehending and rendering movement, we can better understand what assumptions and challenges motivated similar changes in scientific motion visualization.

By the turn of the twentieth century, the visual figure of the fluid line as a symbol for hidden movement was already a central visual motif in scientific visualization. The growing interest in charting invisible phenomena, bodily vitals, and environmental forces was facilitated by instruments that could translate change into a single continuous interpretable form. Such forms included not only the pulsing lines of an oscilloscope or the rolling waves of a statistical sine graph but also the implied lines of change appearing in the interstices of Marey’s chronophotographs, which divested the moving figure of its bodily contour and turned it into a pattern of dots and dashes that could be connected into a single linear pattern.

Nearer to the history of filmmaking, industrial motion scientists Frank and Lillian Gilbreth grappled with the limitations of frame-by-frame photographic studies by developing the method of chronocyclegraphy. In the production of a chronocyclegraph, bright lights were attached to a subject’s hands or joints so that prolonged photographic exposure of the subject’s gestures produced an image of an interrupted line, like an electric doodle, that left a trace of limb trajectories (figure 4). Unlike a photographic series, which tracked the external spatial progression of a moving body by sampling discrete instances of its sequential positions, the chronocyclegraph privileged the overall path of the body’s gestures, making visible the overall arrangement of motion that underpinned the eventual discrete poses. The repetition and variation between different phases of a gestural cycle and its evolution over time become particularly apparent in the overlap and dissonance between the different segments of the line. The moving body itself, visualized through this long exposure, becomes a blurry and indistinct shape beneath the line of its own activity. If a photographic motion study separated the moving body from its background, then a chronocyclegraphic study separated the line of movement from its body. In stilling and fixing the line of activity, the chronocyclegraph turned the dynamic arc of a gesture into a fixed and determined figure, ready for analysis, interpretation, and comparison across different fields. The Gilbreaths even proposed that by using the chronocyclegraph’s line of action the gestures of a factory worker could be compared to the gestures of a surgeon at the operating table,
with the line of action becoming a type of universal language that allowed for the translation of movement across seemingly disparate and incompatible spheres.

The strategy of notating and comparing movements by visualizing them through fixed fluid lines had different but related conceptual consequences for motion studies and for studio character
animation. If one could find out something about the underlying dynamics of human activity by capturing a body’s patterns of movement, could this model extend to other types of elusive or invisible activities, such as movements of the spirit, character, or psychological state? From early lie detection to neurological testing, the lines produced by measuring instruments became a kind of graphic language that allowed for analysis and interpretation of otherwise intangible processes. Elsewhere in graphology and experimental psychology, clinicians strived to interpret the movements of the human spirit through its traces in handwritten and drawn figures.37 These different branches of scientific and pseudoscientific enterprises shared a common assumption about movement: movement was not just a mechanical property of the body but was also a revealing trace of personality or essence, whether it was the essence of the individual or the essence of an activity, such as a state of mind or an ideal pattern for performing a labor task. Strategies for locating and rendering those essential hidden lines of movement would become the foundation of movement notation and visualization. Concrete bodily positions and gestural analysis would follow only in the aftermath, for training or pedagogical purposes.

The line of activity in animation relied on the same connection, building character and personality through notated lines. In interpreting the drawn line as a kind of universal system of legible movement, animation studios such as Walt Disney Studios were able to translate lines borrowed from recorded footage into disparate bodies of fictional cartoon characters. A character’s identity or attitude would be shaped as much by external visual markers (its shape and appearance) as by its way of moving through the world. In the history of the Disney studio, the importance of this shift was marked by the deliberate choice of Snow White and the Seven Dwarfs for the studio’s first feature film. The film’s star character was not the titular Snow White, whose body and movements were closely based on recorded footage of a female dancer, but rather the expressive seven dwarfs. The more distinct personalities of the dwarfs were carefully worked out in advance and endowed with different gestural tendencies. The example in figure 5 by Bill Tytla demonstrates how differently the “animation of forces” looked on paper from the previous pose-by-pose approach. In the bottom row of sketches, even though the distinct details of the body could belong to any one of the film’s seven dwarfs, the particular distribution of weight (coiled and tightly collected pool of lines in one pose and assertively stretched lines in another) establish an identifiable way of moving associated with Grumpy. In the upper row of images, Tytla establishes the characters’ interactions and
creates a blueprint for subsequent assistants by employing a rough and fluid pattern of motion that is reminiscent of a chronocyclegraphic approach. The distinct limb shapes and bodily outlines are almost indiscernible in the upper sketch. The final solid lines that will need to be drawn from frame to frame will emerge somewhere in between the various poses and postures suggested by the arcs of movement (the lines of activity). In fact, one would need to be initiated into the particular code of this notation (either the specific characters of this film or the studio’s animation style more broadly) to understand the nuances of this type of motion choreography.

The crucial function of dynamic lines of activity in both scientifically driven and commercially animated images of movement may provide an additional clue as to why animation became an appealing aesthetic strategy for representations of medical and biological processes. It was not just that animation could visually show optically inaccessible phenomena or portray abstract concepts; the very method of synthesizing movement in animation emphasized underlying trajectories of movement and change over and above specific visual details. Drawn animated films, made by adapting and varying graphic lines, spoke a language of movement that was already familiar to scientific visualization.
Film theorist Andre Bazin provocatively wrote that early scientists of motion, such as Étienne-Jules Marey and Eadweard Muybridge, could not be considered the inventors of the cinema because their work was propelled by an interest in analyzing movement, as opposed to the cinema’s interest in synthesizing motion. And yet for animators, the synthesizers of movement par excellence, scientific analysis of motion became a major strategy for grasping and simulating the dynamics of moving objects. By using the photographic and cinematographic apparatus to study movement, animation could theoretically extract some kind of ineffable properties of motion that would allow filmmakers to generate imagined movements with a foundation of factual kinesthetic accuracy.

In tracing the history of modern scientific objectivity, Lorraine Daston and Peter Galison compellingly argue that the scientific ethos is defined in large part by methods of observation and representation that are developed and promoted in everyday practice: “Perceptions, judgments, and, above all, values are calibrated and cemented by the incessant repetition of minute acts of seeing and paying heed.” By pairing notable examples of scientific motion studies with visual analyses of movement in studio animation guides, I have considered the practice of animation as a different form of “incessant repetition of minute acts” that reveals and rehearses particular perceptions about the world, especially about the nature of living movement. Although this broad definition can extend beyond the practices typically associated with conventional animation and encompass many forms of filmmaking, we can join Alexandre Alexeieff in defining animation as an approach to moving-image production that pays particular heed to the structure and synthesis of movement. In doing so, we can come to recognize and understand the parallels between how scientific visualization and early studio animation negotiated the balance between motion and stasis, or between detail and omission, in studying and representing moving bodies.

These parallels also help account for why animation studios have always been eager early adapters of motion imaging techniques developed in life science and bioengineering labs. Digital motion-capture devices, the most prominent of these techniques, appealed to animation studios not because they could record and digitally replicate an object’s exact visual surface, but instead because they could translate the moving body and face into supposedly characteristic motion data that could then be transferred from actor to character, or from a real body to its animated alter ego.
To recall and modify Alexeieff’s metaphor from the introduction to this essay, digital visualization devices—like the cinematograph before them—could become a microscope through which one might study real movement, visually render invisible types of movement, and generate entirely new forms of motion hitherto unseen.

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**Notes**


2. Alexeieff, “The Synthesis of Artificial Movements in Motion Picture Projection,” 43. We might note, of course, that certain methods of working with photographed images, such as montage or pixilation, also constitute new forms of movement, which are synthesized on the screen for the first time. Perhaps this is why Sergei Eisenstein, the early Soviet filmmaker most closely connected to the development of montage theory and practice, considered his work as fitting the same lineage as Disney animation.


5 In using the term “cinematographic apparatus,” I refer to a wide range of technologies designed to capture or produce moving images, not all of which are necessarily connected to technology widely known as cinema.

6 A number of excellent texts have been published on the history of scientific cinema, including biographical accounts of relevant figures. For a seminal introduction and overview of this history, see Virgilio Tosi, *Cinema before Cinema: The Origins of Scientific Cinematography*, translated by Sergio Angelini (London: British Universities Film Council, 2006). Tosi emphasizes that the Muybridge plates were designed to appeal simultaneously to scientists and artists (71–72).

7 Qtd. in Tosi, *Cinema before Cinema*, 85.


9 Joseph E. Zerga, “Motion and Time Study: A Resume and Bibliography,” *American Psychology* (1944): 477–500. The text indicates that Zerga is writing on behalf of Walt Disney Studios. However, these credentials are most certainly invented, because in other bibliographies written for the journal, Zerga’s occupation is changed and attributed to other companies. The fact that Walt Disney Studios is the company selected to headline the “Motion and Time Study” is indicative of how synonymous the animation studio has become with successful implementation of industrial research on movement and temporality.

10 Ray Hoadley, *How They Make a Motion Picture* (New York: Thomas Crowell, 1939), 101–8. Promotional material for Walt Disney Studios during the early decades also occasionally refers to the studio as a “plant.” See, for example, the promotional documentary *How Walt Disney Cartoons Are Made* (Walt Disney Studios, 1939).


15 Lutz, *Animated Cartoons*, 120. The book also begins and concludes with a prognosis that animation will become the leading filmmaking tool for the portrayal and dissemination of scientific information.

16 Ibid., 38.

17 Ibid., 120.

18 See transcripts of the following Disney action-analysis classes: 12/10/36,
6/21/37, and 6/28/37. Extended gratitude to the John Canemaker Collection at the Fayles Library and Special Collections at New York University and to Michael Sporn for sharing his copies of these transcripts.


21. Ibid., 119.


24. Of course, one of the amusing and clever conceits in this particular film (built around a merry dance of increasingly intoxicated dwarfs) is that the static background is eventually replaced with a fully animated background layer in the final seconds of the film. The new background inserted at the end includes less visual detail, but it is animated to twist and undulate behind the figures, giving the effect of a warped world coming to life and dancing around the drunk characters. This dizzying intoxication effect is achieved precisely because the composition disrupts the otherwise dominant and expected convention of keeping a rigid and static background layer to anchor character movement.

25. Prominent examples include Len Lye’s use of animation stencils, which he combined in different layers and with different phases throughout the 1930s, and John and James Whitney’s arrangements of recurring light patterns into different variations in their film experiments throughout the 1940s.


28. Alexandre Alexeieff called this the “sequence of gaps” or “OTHER HALF” of an animated film (Alexeieff, “The Synthesis of Artificial Movements in Motion Picture Projection,” 46).


31. Disney action-analysis transcript for 6/28/37, John Canemaker Collection at the Fayles Library and Special Collections, New York University.

32. Donald Crafton, *Shadow of a Mouse: Performance, Belief, and World-Making in Animation* (Berkeley: University of California Press, 2012). Crafton calls this period a shift toward “embodied animation,” as the role of natural acting took on a primary role, with the goal of creating fully realized characters that in turn dictated how movement would be constructed and arranged.
33. Disney action-analysis transcript for 6/21/37, John Canemaker Collection at the Fayles Library and Special Collections, New York University.


40. The belief that certain patterns of movement can reflect underlying personality or character intentions persists, which is why CGI films and game producers still rely on recording particular actors and why microgestures and micromovements become increasingly important for motion capture. In one recent popular video game, L.A. Noir, part of the game’s objective is to be able to discern truth or deception in a character’s bodily gestures or facial expressions—a conceit developed in large part to take advantage (with mixed success) of more nuanced and accurate facial movement registration.