Special Section

ArtScience: The Essential Connection

Guest Editor: Robert Root-Bernstein

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Deconstructing the Genome with Cinema

Gabriel A. Harp

ABSTRACT

Evidence from language, history and form suggest an analogy between the cinema and the genome. The author describes some of the relationships between cinema and the genome and points to opportunities for discovering unmarked categories within the genome and new methods of representation. This is accomplished by evaluating existing metaphors presented for the understanding of genetics and revealing how current scientific understanding and social concerns suggest a cinematic alternative. The formal principles of function, difference and development mediate discussion and serve as heuristics for investigating creative opportunities.

Modeling Life

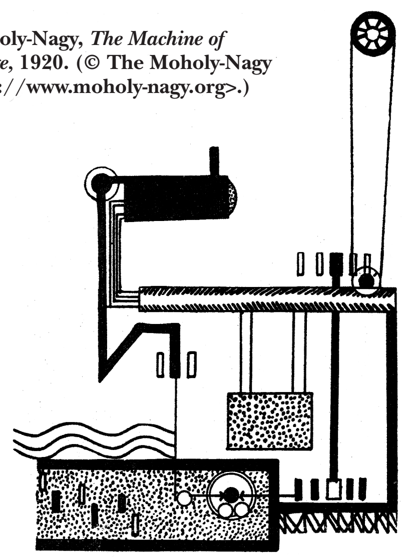
Concerned with how to represent their ideas, discoveries and scientific models to both specialists and a non-technical public, biologists, designers, artists and journalists often turn to metaphors as a means to introduce and describe natural processes (e.g. Fig. 1). Scientific models are often judged by both scientists and the public on their appeal to consistency with other belief systems, models and metaphysical commitments [1]. This search for consistency has led some biologists to recognize that creative media, like living organisms, can provide sources of information for studying life. Computer simulations, for example, allow biologists to test their assumptions *in silico* and to demonstrate life processes using structured mathematical languages. Around the time that these computational methods began to emerge as a tool of biology, influential embryologist and art critic C.H. Waddington emphasized the similarities among forms created by people and those created by nature. As a comparative biologist, Waddington used static objects such as bones and fossils to infer biological causality, but he also identified film's unique ability to record change as a possible observational tool for studying growth and form.

> When, or if, cinema becomes the most important technique of artistic creation, and movement one of the fundamental raw materials out of which beauty is created, then, perhaps, we shall have to turn our attention to the aesthetic characteristics of developmental processes [2].

Waddington's concern for aesthetics was representative of many biologists, including Charles Darwin, who based their standards of evidence on comparatively similar structures among organisms. These organic structures displayed a visual similarity that gave clues to the most scientific and parsimonious explanations for evolution. However, unlike many, Waddington looked beyond organic forms for scientific inspiration. In film, Waddington recognized an "organicist holism" [3] that also characterizes the irreducible complexity of an organism. Since these early comparisons, the elements of film have been further articulated, as has the genetic basis of organismal development. Consequently, we can build on the success of these descriptions and recognize that cinema and the genome share a structural similarity.

Analogy and reconfiguration are rich sources of new hypotheses. Analogy and metaphor provide a scaffold of natural experience with which to support and extend our understanding of a concept, create similarities and transform reality [4]. Positing that the genome and genomics are analogous to film and cinema (Article Frontispiece) is consistent with other uses of analogy; it has the potential to reconfigure both domains, because it allows for the identification of otherwise unmarked classes without the restrictiveness of a literal translation [5]. For example, although costume and make-up are not subjects of discourse in genomics, they may create new ideas about what genes might "wear" when one attempts to resolve their incompatibilities in the genomics context. However, there is a key distinction in the choice of analogy rather than metaphor to describe this comparison. By attributing a certain amount of homology to structures that are otherwise dissimilar, analogy implies deep connections and/or causative relationships that bring practical description and understanding. When we use an analogy as opposed to a metaphor, we take the first step toward an analytical synthesis of differences in a comparison of seemingly unrelated structures. Indeed, the cognitive stage seems to be set for a systematic comparison between the genome and cinema.

Fig. 1. László Moholy-Nagy, *The Machine of Emotional Discharge*, 1920. (© The Moholy-Nagy Foundation, <http://www.moholy-nagy.org>.)



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Article Frontispiece. Gabriel A. Harp, *Chromosoma*, 2006. (© Gabriel A. Harp) In this installation view, a visual analogy is made between folded lengths of 35mm movie film and chromosomal structure. New pairings of unrelated images may be found in accidental crossovers of the film.

Fig. 2. A visual comparison is usually the indicator of convergent evolution. (Photos © Gabriel A. Harp) A new world variety of succulent cacti (left) and an old world variety of euphorbia (right) have similar spine and stem morphology.

This post–genomic-cinematic comparison is stimulated by language and the patterns apparent in genomic structures now that genome-sequencing projects are complete. An initial clue is that metaphors such as editing, splicing and sequencing permeate molecular biology and cinematic discourse. Computational tools for investigating genomic sequences use such names as CINEMA and THEATRE [6], presenting themselves as holistic tools for comparing and discovering hidden sources of meaning while further suggesting the broad applicability of this analogy as a bioinformatics tool. In evolutionary biology, analogy substantiates claims of convergent evolution—for example, that the spines of succulent African euphorbias and the cacti of the Americas have comparable morphology without being closely related (Fig. 2). Wing structures in bats and birds also demonstrate how similar functions have arisen independently from similar evolutionary pressures or developmental constraints. Just as we can ask what forces or constraints give rise to and maintain structures in birds, mammals and plants, we can ask how similar meanings are constructed using film and the genome.

Genomic Metaphors

It is necessary to recognize that several persistent metaphors guide popular (mis)conceptions of the genome. In the years surrounding the "revelation" of the human genome sequence, many critics have counseled the application of metaphor in public discourse and discussed the social and scientific implications of its use [7]. Since then, cultural, media domain and metaphor analyses have examined the outcomes of scientific and political discourse about the genome with the public [8].

The most enduring metaphor is that of a "map," which serves the useful function of being applicable to a range of situations across wide swaths of time. Maps appeal to our visuospatial cognitive abilities. They are invoked whenever significant unknown conceptual territory looms on the horizon, however they are limited as metaphors because the sexes [9] do not interpret them in the same ways. Genetic maps are fetishized objects [10], post-genomic artworks, useful for displaying and intervening in the processes that spawned their production and for strategizing impending invasions into unknown lands or, in this case, bodies [11]. Hall, however, finds that the spatializing effects of genetic maps in organizing and structuring sets of "truths" tend to exclude alternative biological processes and social contexts [12]. Ultimately, maps may be useful tools for those doing the research, but for generalized public understanding, a diversified array of representations may be more appropriate and engaging.

Another metaphor suggests that genetic maps are "intelligently designed" to guide us during a journey of twisting paths and moral judgments. When it comes to describing the genome in its biomedical research context [13], the Holy Grail that is invoked is most commonly the grail of Christian journey metaphors. However, like other navigational metaphors, this one has its limitations because it does not refer to anything inherently spatial [14]. This specific legend implies a search bound by moral fortitude, focused on an elusive object, and motivated by revelations of God's divine message through promises of eternal life [15]. Perhaps what we ought to take from this or any "journey" metaphor is the idea of process, whereby we are constantly in the process of constructing "the genome" from a complex meeting of physical, cultural and mental representations.

Still, if we were to consider that God's messages populate the "mapped genome," how can we read and interpret them? The notion that the genome is a code to be solved, cracked, translated and deciphered is a pervasive metaphor of scientific and public discourse [16]. "Codes" can be easily extended to include languages that need to be translated from or into blueprints, recipes and books. "Translation" permeates molecular biology in reference to processes that assemble protein molecules from messenger RNA. Book and blueprint metaphors have turned the genome into an object rather than an ongoing series of questions.

Van der Weele reveals some sources of metaphor that situate DNA as *the* causal mechanism for organismal development and argues that these metaphors exclude the effect of the environment as a causal mechanism in biological development, and impede a more nuanced and complete understanding of nature [17]. When DNA is placed in this role, it contributes to masculinist power and control metaphors that sustain a worldview in which someone has to be in charge—all despite the fact that DNA is a relatively inert molecule [18].

The difficulty with these metaphors is that, for some, these paths point to an intelligent designer. Implicit promises of fulfillment, proclamations touting codes and maps, and "Holy Grail" language do as much to entrench the idea of intelligent design within public perception as any school board–ordained middle-school textbook ever could. Even without religious undertones, codes and books imply that a single author has written them. The pressing question becomes, "Who wrote the book of life?" How does a public resolve these mixed messages from a scientific community that is complicit with these metaphors when it benefits biomedical research funding and aghast when intelligent design proponents challenge contemporary evolutionary theory and funding?

Precedents: New Opportunities

Despite these historical precedents, many creative individuals have developed alternative methods for communicating the genome's complexity in a pluralistic society. Music continues to provide a welcome departure from traditional genomic metaphors, offering explanations rooted in jazz [19] and software-mediated translations of genetic-sequence data into aural representations [20]. Still, music relies on a text or code that, again, only a skilled group can translate. Music employs repetition to achieve basic functions of meaning and in that sense is more akin to the genome than any of the aforementioned metaphors. Ohno and Ohno have conceptualized the transdisciplinary meanings generated by viewing genomic repetition as a source of inspiration and novelty:

> "Whereas ordinary mortals are content to mimic others, creative geniuses are condemned to plagiarize themselves" is my shorter, albeit inarticulate, version of what Van Veen said in *Ada* by Vladimir Nabokov. Indeed, it seems that vaunted geniuses seldom invented more than one modus operandi during their lifetimes, and even civilization has largely been dependent upon plagiarizing a small number of creative works; e.g., the multitudes of Gothic churches can be viewed as pan European plagiarism of the abbey church of St. Denis and/or the cathedral at Sens. This is not surprising for new genes *sensu stricto* have seldom been invented. Evolution rather relies on plagiarizing an old and tested theme; the mechanism of evolution by gene duplication. . . . This principle of repetitious recurrence pervades both the construction of coding sequences in the genome, which can be regarded as being representative of nature, and musical composition, which can be regarded as the most abstract and therefore the most intellectual expression of nature [21].

In joining the concepts of linearity and plagiarism, Ohno and Ohno ignite a relationship between two of the most ancient expressions of nature and humanity, that of the genetic code and music composition. Both of these forms demonstrate our awareness of disguised originality, in that the repetition of existing forms provides the substrate for all new meaning. This is a basic feature common to both cinematic and genetic systems.

Metaphors for the genome include visual arts processes. Plant-developmental biologist Enrico Coen compares gene organization and structure to the steps involved in the development of a painting [22]. Similarly, McMeekin [23] has shown how Diego Rivera's *Detroit Industry, South Wall* and *Healthy Human Embryo* in the courtyard of the Detroit Institute of Arts compare the industrial and collective development of an automobile with the embryonic development of a human being. Avise [24] concludes that the functional collaborations characterized by "an interactive community . . . may be especially useful and stimulating at this time." Because we are searching for new working metaphors for the genome [25], the social collective seems to be finding a niche as an ad hoc committee [26] or a cast of characters [27]. These new metaphors emphasize cooperation and point again to the ideas of process, interaction and context.

We are unlikely to unhinge ourselves from previous metaphors that rely on a text, but we can incorporate new insights and scientific concepts. What began as a map, a text or a journey can now be complemented with sound, visuals and cooperation among individuals and groups. Of all cultural forms, few bring these elements together as well as cinema.

Historical Convergence

By 1929 the study of embryos and their development was foreshadowing genomic biology. Scientists sought alternative explanations for a gene concept that was rapidly being incorporated (and ultimately confirmed) by Darwinian evolutionary theory [28]. Soviet biologists were at the heart of the debate, and it was in 1929 that Soviet filmmaker Sergei Eisenstein made this comparison: "The [cinematic] shot is a montage cell (or molecule)"; "just as cells in their division form a phenomenon of another order, the organism or embryo, so, on the other side of the dialectical leap from the shot, there is montage" [29]. This was a telling analogy, using well-established observations from embryology to describe his new approach to cinematic form. As Gilbert and Faber have pointed out [30], the filmic language of editing, framing and composition used by Eisenstein was similar to that of his embryologist contemporaries, who were consistently making comparisons among developing cells. Indeed, embryology has a set of visual preferences distinct from other forms of biology [31] and shares with film an aesthetic similarity. This aesthetic similarity comes, as least in part, from the formal principles (e.g. similarity and difference) that we use to identify patterns in nature and other systems of meaning.

Landecker [32] also considers Eisenstein's analogy, along with the statement by Walter Benjamin [33] that the cell is "more native to the camera than the atmospheric landscape or the soulful portrait." Like Waddington, she identifies photography as the appropriate domain from which to study embryogenesis. Landecker goes on to reveal how the "teeming presence" of the cell in early cinematic culture was part of scientific and cinematic concerns over how to represent life. Recalling Kracauer's connections between the gaze of cinema and its origins in scientific filmmaking [34], Landecker describes how early scientific films became critical to the development of the cinematic form. She illustrates the shared desires of scientists and filmmakers to describe the shape of life and its minute relationships using film and maintains that Kracauer's kinship model of science and the cinema is not borne out of any shared attempt to record "objective" reality. A relationship between early cinema and life science was forged through their shared, changing visual and written languages, based on the psychological representation of language processes rather than representation of objects such as the cell or genome [35]. It was from these early relationships that new artistic and scientific ideas were generated.

Genomic Cinema

Genomic Cinema refers to any process whereby the language of the genome is translated into the language of cinema or vice versa. The principles of function, repetition, difference, development and unity promote structure and provide the grammar for film [36] and for genetic languages. Here I give just a few examples as a brief introduction to this formal comparison.

Function

Genomics is divided into two areas. Structural genomics is concerned with DNA sequence organization, while functional genomics identifies the roles that individual genes play and their interactions within the genome as a whole. An example of a gene's function is its role during cell division or in the transport of materials. Genes may serve multiple functions indicative of their cooperative roles during the life of a cell or organism. Some heat-shock proteins are involved in metabolism, DNA repair, stress responses and a cell's sensing of its environment.

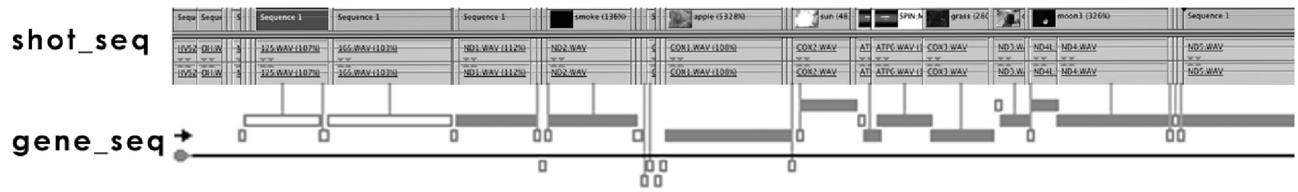

Fig. 3. A visual comparison demonstrated (bottom) by the minimalist database representation of the human mitochondrial genome (National Center for Biotechnology Information, Map Viewer) and (top) a digital video-editing track copied from Final Cut Pro. (Final Cut Pro, Apple, Inc.) Even though both sequences can be linear, they are often compiled and realized non-linearly.

Similarly, shots in a film perform various functions that drive the story. In Victor Fleming's *Wizard of Oz* (1939), sequences of Toto initiate Dorothy's journey to and from Oz, but Toto's grey color also provides a counterpoint to the bright color of Oz and a link to the black-and-white beginning and end scenes of Kansas [37]. The Ferrari sequences in *Ferris Bueller's Day Off* by John Hughes (1986) provide a means of transportation to and from the city as well as the source of and solution to conflict between Cameron and his father. Functions are descriptions of the tasks that sequences or shots play in the overall plot, whether in the genome or film.

Difference (With a Slight Aside)

Playing with repetition and using the concept of difference, Eisenstein created cinematic meaning within the philosophical framework of dialectical materialism. Dialectical materialism is the philosophical idea that the physical processes of the natural world regulate conflict and synthesis between opposing or different forces. This view was extremely important for embryologists in the 1920s through the 1950s [38] and implicit for some evolutionary geneticists [39]. Eisenstein held the belief that art is conflict and arises from the "evolutionary synthesis" of an interaction between two contradictory opposites. This *synthesis* of opposites is an essential concept, because it recognizes that benchmarks, thresholds or, at least, endpoints, demarcate the unfolding story [40]. For developmental biologists a story is an organism; for filmmakers, the story is the cinematic experience of the viewer. Likewise, contemporary evolutionary and developmental biologists recognize that conflicts within an unfolding organism stem from its relationships and interactions with its historical past, physiological present and ecological future. As such, dialectical materialist methods have been and continue to be advantageous for understanding dynamic relationships in nature and evolutionary processes [41], because they allow for multiple comparisons among many different sources of meaning.

Development

We can think of development as the change or progression of a story or an organism. Developmental change is dependent on the patterning of repetition and difference in the genome. Homeotic gene regions organize pattern formation in plants and animals as complexes that reside in close proximity on the chromosome [42]. These loci are thought to have diversified from multiple chromosomal duplication events (i.e. repetition), while their role in development is temporally and spatially collinear. This means that gene expression (when it is turned on or off) is correlated in time and space, with a gene at the "beginning" of the complex expressed in one region of the body early in development, while a gene at the "end" of the complex is expressed both late in development and in another body region. This would seem to indicate that gene expression is linear with respect to the location of genes along the chromosome [43]. These homeotic loci demonstrate modular repetition that, due to temporal changes in the timing and organization of their expression, can yield expansive diversity in form and function. Thus, it is rare for genes involved in pattern formation to have a part in only one developmental decision.

Pattern formation happens similarly in cinema. Interestingly, both biologists and film analysts use segmentation—in the organism and the film, respectively—to analyze patterns of development. Bordwell and Thompson [44] describe how, in the *Wizard of Oz,* Professor Marvel furthers the development of the film. At the beginning of the film Dorothy tries to visit him, while at the end he visits her. He is also present as the Wizard of Oz, representing her hopes to return home. Thus, in the development of the film from journey (away from home) to search (for the Wizard) and finally mystery (Who is the Wizard of Oz?), Dorothy basically encounters the same individual. This development happens because that individual is expressed differently according to other repetitions (e.g. relationships with family) happening in the film, as well as temporal (story progression) and spatial differences (Kansas vs. Oz). The resulting interplay of function, similarity and difference create dynamics that contribute to the development of the cinematic form.

Discussion

These examples emphasize similarity of form (Fig. 3). Framing genomic architecture against the cinematic form suggests that the creation of meaning in artistic domains can transgress the constructed boundaries of science and vice versa. The benefits are partially perceptual, allowing us the opportunity to recognize gaps in our knowledge. For genetic counselors, public health practitioners, biologists, politicians, artists and others, genomic cinema can be a useful analogy for communicating knowledge, addressing public concerns and building empathy among individuals.

Like all analogies, this one has its limitations. As a film instructor, I can attest to the difficulties that many students face when first learning about the systematic interpretation of cinematic form and meaning. However, the success of the medium clearly demonstrates how easily communication can occur at some level. Genomic cinema also creates the possibility of uncertain futures that may be as problematic as those we currently face. Genetics and visual media are currently experiencing a shift toward digital encoding, storage and control. Synthetic biologists have begun to explore these issues with microorganisms, their genetic architecture acting as genetic switches or devices. As these experiments unfold, questions need to be asked about how we translate the genome and turn its stories into a visual and/or mechanistic vocabulary.

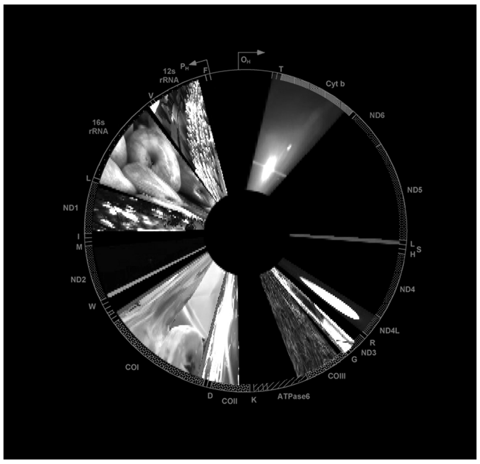

Fig. 4. Gabriel A. Harp, *mtMAP*, digital video, 10 min, 2004. (© Gabriel A. Harp) In this video, the human mitochondrial genome is used as a template for the creation and organization of symbolic images.

Ultimately, the goal of using cinema to deconstruct genetic architecture is to reveal structures and relationships that become suppressed by the static uses of metaphor. By supplanting filmic repetitions, layers and interpretations in place of existing genomic metaphors, we may find an expanded set of representations in a direct appeal to the range of human sensations (Fig. 4). Furthermore, when current cultural debates use metaphors that contribute to religious and scientific misunderstandings, we ought to examine our uses of language and suggest alternatives. The genomic cinema analogy suggests such an alternative and provides creative research opportunities for investigating dynamic grammars within the cultural context and hopeful vision of our time.

References

1. J. Cartier, J. Rudolph and J. Stewart, "The Nature and Structure of Scientific Models: Working Paper" (Madison, WI: The National Center for Improving Student Learning and Achievement in Mathematics and Science, 2001) pp. 5–6, <www.wcer.wisc.edu/ncisla/publications/reports/Models.pdf>.

2. C.H. Waddington, "The Character of Biological Form," in L.L. Whyte, ed., *Aspects of Form* (London: Lund Humphries, 1960) p. 44.

3. S.F. Gilbert and M. Faber, "Looking at Embryos: The Visual and Conceptual Aesthetics of Emerging Form," in A.I. Tauber, ed., *Aesthetics and Science: The Elusive Synthesis* (Boston, MA: Kluwer, 1996) pp. 138–139.

4. G. Lakoff and M. Johnson, *Metaphors We Live By* (Chicago, IL: University of Chicago Press, 1980) pp. 117, 145–155.

5. C.Z. Elgin, "Creation as Reconfiguration: Art in the Advancement of Science," *International Studies in the Philosophy of Science* **16**, No. 1, 13–25 (2002).

6. D.J. Parry-Smith, A.W.R. Payne, A.D. Michie and T.K. Attwood, "CINEMA—A Novel Colour INteractive Editor for Multiple Alignments," *Gene* **211**, No. 2, 45–56 (1997); Y.J.K. Edwards et al., "Theatre: a Software Tool for Detailed Comparative Analysis and Visualization of Genomic Sequence," *Nucleic Acids Research* **31**, No. 13, 3510–3517 (2003).

7. G.A. Petsko, "The Rosetta Stone," *Genome Biology* **2**, No. 5, 1–2 (2001); L.E. Kay, *Who Wrote the Book of Life? A History of the Genetic Code* (Stanford, CA: Stanford Univ. Press, 2002); C.M. Condit et al., "Recipes or Blueprints for Our Genes? How Contexts Selectively Activate the Multiple Meanings of Metaphors," *Quarterly Journal of Speech,* No. 88 (2002) pp. 303–325; and E.F. Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology,* The Wellek Library Lecture Series at the University of California, Irvine (New York: Columbia Univ. Press, 1995).

8. *New Genetics and Society* **24**, No. 3 (2005); L. Ceccarelli, "Neither Confusing Cacophony nor Culinary Complements: A Case Study of Mixed Metaphors for Genomic Science," *Written Communication* **21**, No. 1, 92–105 (2004).

9. D. Halpern and M. Collear, "Sex Differences in Spatial Abilities: More Than Meets the Eye," in Priti Shah and Akira Miyake, eds., *Cambridge Handbook of Visuospatial Thinking* (New York: Cambridge Univ. Press, 2005) pp. 170–112.

10. D.J. Haraway, *Modest_Witness@Second_Millennium. FemaleMan©_Meets_OncoMouse*™ (New York: Routledge, 1997) pp. 135–137.

11. E. Larsen and S. Millner, "Mapping the New World," *Art Journal* **59**, No. 3, 54–58 (2000).

12. E. Hall, "Reading Maps of the Genes: Interpreting the Spatiality of Genetic Knowledge," *Health & Place* **9**, No. 22, 151–161 (2003).

13. See Gilbert, quoted in R. Lewin, "Proposal to Sequence the Human Genome Stirs Debate," *Science,* No. 232 (1986) pp. 1598–1600.

14. D.R. Montello, "Navigation," *Cambridge Handbook of Visuospatial Thinking* [9] pp. 257–294.

15. Critical Art Ensemble, "Body Invasion and Resistant Cultural Practice," *Art Journal* **59**, No. 3, 48–50 (2000).

16. See, for example, Petsko [7]; Kay [7].

17. C. Van der Weele, *Images of Development* (New York: State University of New York Press, 1999) pp. 19–45.

18. R.C. Lewontin, "In the Beginning Was the Word," *Science* **291**, No. 5507, 1263–1264 (2001).

19. M. Porta, "The Genome Sequence Is a Jazz Score," *International Journal of Epidemiology,* No. 32 (2003) pp. 29–31.

20. J. Dunn and M.A. Clark, "Life Music: The Sonification of Proteins," *Leonardo* **32**, No. 1, 25–32 (1999).

21. S. Ohno and M. Ohno, "The All Pervasive Principle of Repetitious Recurrence Governs Not Only Coding Sequence Construction but Also Human Endeavor in Musical Composition," *Immunogenetics* **24**, No. 2, 71–78 (1986).

22. E. Coen, *The Art of Genes: How Organisms Make Themselves* (Oxford, U.K.: Oxford Univ. Press, 2000) p. 24.

23. D. McMeekin, *Diego Rivera: Science and Creativity in the Detroit Murals* (East Lansing, MI: Michigan State Univ. Press, 1985) pp. 29–33.

24. J.C. Avise, "Evolving Genomic Metaphors: A New Look at the Language of DNA," *Science* **294**, No. 5540, 86–87 (2001).

25. J. Turney, "The Sociable Gene," *EMBO Reports* **6**, No. 9, 808–810 (2005).

26. L. Moss, *What Genes Can't Do* (Cambridge, MA: MIT Press, 2003) pp. 188–190.

27. G. Pappas, "A New Literary Metaphor for the Genome or Proteome," *Biochemistry and Molecular Biology Education* **3**, No. 1 (2005) p. 15.

28. S.F. Gilbert, J.M. Opitz and R.A. Raff, "Resynthesizing Evolutionary and Developmental Biology," *Developmental Biology* **177**, No. 2, 357–372 (1996).

29. S. Eisenstein, *The Cinematic Principle and the Ideogram in Film Form* (New York: Harcourt Brace Jovanovich, 1949) p. 37.

30. Gilbert and Faber [3] p. 139.

31. Gilbert and Faber [3] p. 125.

32. H. Landecker, "Cellular Features: Microcinematography and Film Theory," *Critical Inquiry,* No. 31 (2005) pp. 903–937.

33. W. Benjamin, "Little History of Photography," in Michael W. Jennings et al., eds., *Selected Writings,* Vol. 2, Rodney Livingstone et al., trans. (Cambridge, MA: Harvard Univ. Press, 1999) p. 512.

34. S. Kracauer, *Theory of Film: The Redemption of Physical Reality* (New York: Oxford Univ. Press, 1960) pp. 20, 50, 52.

35. Landecker [32].

36. D. Bordwell and K. Thompson, *Film Art: An Introduction,* 7th Ed. (New York: McGraw Hill, 2004) pp. 59–65.

37. Bordwell and Thompson [36] p. 60.

38. Gilbert et al. [28]; Gilbert and Faber [3] p. 135.

39. R. Levins and R.C. Lewontin, *The Dialectical Biologist* (Cambridge, MA: Harvard Univ. Press, 1985).

40. Gilbert and Faber [3] p. 139.

41. Levins and Lewontin [39]; B. Clark and R. York, "Dialectical Nature: Reflections in Honor of the Twentieth Anniversary of Levins and Lewontin's *The Dialectical Biologist,*" *Monthly Review,* No. 57 (2005) pp. 13–22.

42. S. Freeman and J.C. Herron, *Evolutionary Analysis* (Upper Saddle River, NJ: Prentice Hall, 2001) pp. 588–589.

43. Freeman and Herron [42] p. 589.

44. Bordwell and Thompson [37] pp. 64–65.

Manuscript received 19 September 2005.

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