



## Computer Versus Microscope: Visual Activity Fields of Instruments in the Information Age

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**Source:** *Spontaneous Generations: A Journal for the History and Philosophy of Science*, Vol. 7, No. 1 (2013) 81-93.

**Published by:** The University of Toronto

**DOI:** [10.4245/sponge.v7i1.16151](https://doi.org/10.4245/sponge.v7i1.16151)

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Published online at [jps.library.utoronto.ca/index.php/SpontaneousGenerations](http://jps.library.utoronto.ca/index.php/SpontaneousGenerations)  
ISSN 1913 0465

Founded in 2006, *Spontaneous Generations* is an online academic journal published by graduate students at the Institute for the History and Philosophy of Science and Technology, University of Toronto. There is no subscription or membership fee. *Spontaneous Generations* provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

PEER-REVIEWED

# Computer Versus Microscope

## Visual Activity Fields of Instruments in the Information Age<sup>\*</sup>

Mauro Turrini<sup>†</sup>

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The increasing concern about visual representation in science has been usually converged on representations—photographs, diagrams, graphs, maps—while instruments of visualization have been usually neglected, because of the difficulty in concretely grasping their effects on visualization. In this regard, the questions and concepts formulated in the debate on digital visualization serve here as a starting point to analyze the change in instrumental mediation triggered by the introduction of computer-assisted imaging technologies in those laboratories that traditionally have used and still use microscopes. Empirical materials gathered during an ethnographic investigation of Italian cytogenetics labs are here presented to show the visual spaces provided by microscopes and digital systems as activity fields, which are inhabited by and suggest in an either divergent or complementary way specific practices, materials, organizations, epistemological orientations and aesthetical preferences.

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This paper intends to explore the introduction of computer-assisted imaging technologies in scientific laboratories that traditionally have used—and still continue to use—optical microscopes. The transition from optical to digital imaging technologies is usually presented as a straightforward shift aimed at both reducing time and cost, as well as increasing the accuracy of visualization procedures. Instead, in the clinical cytogenetics case study, this passage has generated tensions over the ways in which visual legibility is constructed through the alternate optical spaces of microscopes or through the computer screen. In this sense, cytogenetic laboratories (particularly Italian clinical ones) represent an ideal area of investigation. Firstly, this discipline revolves around the construction of visually legible chromosomes to be analysed, or “read,” according to the lab’s vernacular. Secondly, cytogenetic procedures of chromosome representations, although well-established, are still fraught

<sup>\*</sup> Received 29 February 2012. Accepted 17 January 2013.

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with indeterminacies, which are always essential to overcome for diagnostic purposes. Thirdly, the local and contingent strategies used are usually stratified and consolidated in diverse “styles” (Turrini 2012), which have been kept alive by the diversities which characterize the relatively large community of cytogeneticists engaged in hospitals and clinics. This is particularly evident in the highly fragmented context of Italian health service, where as of 2004 there were more than 160 cytogenetic labs.<sup>1</sup> Within this plurality of styles of visualizing chromosomes, what interests us are the ways in which optical and digital viewing technologies are used differently according to the preferences of lab heads or individual scientists. Computer-assisted imaging systems have already been introduced to replace microphotography in the preparation of the archival files that are produced for each diagnosis. However, thanks to the new generation of software, the role of the computer has progressively extended until it has become crucial for the process of analysis itself. This raises questions about the quality of digital visualization, which is seen at the same time as both more accurate and more adulterated: digital visualization allows the observation of something that is imperceptible through the microscope, but also introduces artifacts into representations. As a result, while some scientists carry out almost the whole analysis on the digital space of computer screen, others prefer the optical space of microscope.

What is discussed here is not the resistance or skepticism towards the stabilization of new digital technologies. Rather, the aim of this paper is to examine the tensions between different imaging technologies and to delve into the multiple interconnections between imaging technologies—particularly their visual space as an activity field—and the embodied practices, procedures, architecture, and organization which form the local order of a laboratory. Studies of scientific visual phenomena have tended to focus on representations (graphs, photographs, diagrams, maps and other inscriptions) understood in their connection to a nexus of scientific practices, like observation, measurement, description, and demonstration (e.g. Lynch and Woolgar 1990; for a review see Lynch 1998), or in their effects on conceptions of truth, sight, and evidence (e.g. Daston and Galison 1992; 2007; Joyce 2005; for a recent review see Perrotta 2012). The concern of the present paper, instead, is not to look at the processes, or the nature and status of the *images produced*, but to explore the practices and interconnections of the *instrument of visualization*, which is to be considered as a space of intersubjectivity embedded in the texture of the heterogeneous elements of a laboratory.

More specifically, the object of this analysis is how scientists themselves

<sup>1</sup> The survey by Dallapiccola and colleagues on genetic tests in Italy has monitored the activity of “88 clinical centres, 160 cytogenetic and 183 molecular genetic laboratories [...] hosted by 256 structures” (Dallapiccola *et al.* 2006, 192).

inhabit, organize, construct and question the social and material *visual field of activity* provided or, in Gibson's (1986) terms, "afforded" by microscopes or computer-assisted imaging systems in use in cytogenetics. By focusing on the ordinary methods that cytogeneticists use in their ordinary activities, this paper draws upon the ethnography of science (Latour and Woolgar 1986; Lynch 1985) and, more particularly, uses an ethnomethodological approach to the understanding of knowledge practices involving the visual realm (Lynch 1991). After a brief review of the academic discussion regarding cyborg visuality, I will present empirical materials resulting from a two-year ethnographic investigation in Italian clinical cytogenetics labs.<sup>2</sup> This data shows the many ways in which these two instrumental spaces—optical microscope and computer screen—are characterized by specific and sometimes divergent work practices, divisions of labour, and epistemological and aesthetical theories of representation.

### I. OPTICISM AND DIGITALITY

Generally, the shift from *analogue pictures*, with their continuous spatial and tonal variations along which an indefinite amount of information is contained, to *digital images*—which are simultaneously a precisely fixed array of "image data" that can be manipulated, transmitted, and replicated without degradation—has challenged the authority of realism established by photography in favour of a new kind of "visual truth" (Mitchell 1992). A similar change has been noted by several sociological and historical investigations regarding the introduction of computer-assisted imaging technologies in scientific and medical realms. Investigating Magnetic Resonance Imaging, Amit Prasad (2005) showed that digital imaging technologies, although sharing some similarities with analogue imaging, bring the medical gaze into a "new visual regime," called "cyborg visuality." Cyborg visuality works within a different framework of realism that does not seek an "objective" or "mechanical reproduction" (Daston and Galison 1992) of the observed object(s), but rather seeks a production of differential, multiple, and partial viewings through the interaction between humans and machines. Extending the argument of the manipulability allowed by digital visualization, Lorraine Daston and Peter Galison (2007) argued that the introduction of new computer-assisted imaging technologies wrenches the scientific image out of a long historical track centred on "objectivity,"

<sup>2</sup> The observation was conducted between 2008 and 2009 in three clinical cytogenetics laboratories in Italy: one large private lab, and two smaller public ones. The methodology adopted was a participant observation; laboratory work routines were observed for a period of six months, in-depth "ethnographic" interviews were conducted with over twenty practitioners including physicians, biologists and technicians, three courses were attended in order to understand standardization in cytogeneticists' laboratory routines, leading to the analysis of protocols, guidelines and handbooks.

according to which inherent properties of an object can be ascertained only by means of a disciplined struggle against any observer's intervention in the representation provided by machines. Discussing virtual anatomical and cutting-edge nanotechnologies of imaging, where pictures are used to alter the physical world in real time, the two historians described this break in terms of a shift from the image as a faithful representation of nature to the image as a tool to make and change things. Imaging can then be seen as an interactive process whereby "digital images are meant to be *used*, cut, correlated, rotated, coloured" (Daston and Galison 2007, 383).

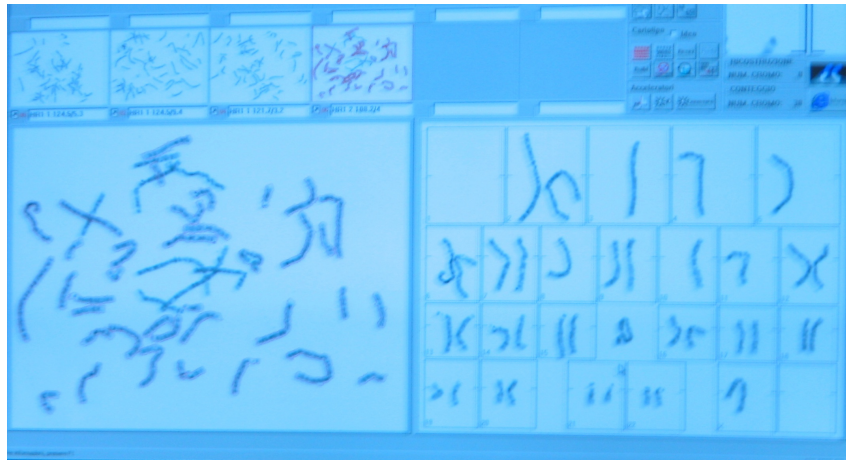
Michael Lynch analysed "opticism" and "digitality" in terms of human/machine relationship and defined them as "technological complexes," whose paradigms are respectively "the lensed instrument and the scrutinized eye," and "the play of fingers (digits) on a keyboard instrument" (Lynch 1991, 62). He treated optimism and digitality as two particular Foucauldian discursive formations that, even if associated with two distinct historical periods (the Renaissance discovery of linear perspective and the computer age), were not "incommensurable or discontinuous...[but rather] what Garfinkel has called 'asymmetrical alternates.'" He argued that digitality was not totally new, but yet may undermine optimism, while the opposite process is not possible. Discrete representational techniques existed in earlier "optical" techniques. However, in the visual space inhabited by the eyewitness of the photographic subject (or the microscope user), "machines [stand] with authenticity" (Daston and Galison 2007, 129). On the contrary, the advent of digital imaging technologies has replaced the static field with a diachronic, interactive process, which may underpin or simulate the operative conditions of optimism. As this work shows, the introduction of digital visual technologies has introduced new questions about the social analysis of representations. What is at stake is no longer the nature and status of scientific representations, but rather the relationship between imaging technologies and practices.

More recent studies on digital imaging have shed light on the important role played by the computer screen as a place of intersubjective interaction for scientists in the process of reconfiguring evidence. In her ethnography of functional MRIs, Morana Alač (2008; 2011) has clearly shown the interaction between practices of digital images and the production of scientific objects. To rephrase the title of her monograph, visual representation opens up new ways of handling scientific objects. Likewise, other works on digital visualization have shown how the dynamic character of digital images has to do not only with the way they are represented, but also with the ways in which they are constructed and pragmatically treated as material objects (Monteiro 2010a; Myers 2008). Drawing on this literature, the specificities of the instrumental fields of two alternative imaging technologies—the microscope and the computer—are analysed here as intersubjective spaces through which

the concrete organization of the scientific laboratory is achieved and where different manners of visualizing and viewing the same scientific objects—human chromosomes—are deployed.

## II. THE NEW PERCEPTUAL FIELD OF THE AUTOMATED DIGITAL IMAGE SYSTEMS

Computer-assisted imaging systems were introduced in cytogenetics labs at the end of the 1980s in order to reduce the time it takes to “karyotype”—i.e. to prepare “karyograms.” Karyotyping is the final stage of the visualization of chromosomes. Given that chromosomes are dynamic histological structures, the process of representing them is articulated and labour-intensive. The process consists of arresting their cycle of development at the point of division (“metaphase”), then disentangling them from any other cellular materials that may be mistaken for them, and finally staining them with dyes that highlight the regions of interest. In a “metaphase plate,” chromosomes are messily spread and are often touching each other, overlapping or adjacent to non-chromosomal material or to chromosome of another cell. We can see karyotyping as the theoretical, classificatory *space of order*. Chromosomes are arranged by size in pairs and classified according to their unique distinguishing characteristics, as derived by position of “centromere” (the visible constriction in the centre) and banding pattern; more specifically “homologous” chromosomes are numbered (for humans species from one to twenty-two), and “sexual” chromosomes are identified by the letter X or Y (Fig. 1).



**Figure 1.** A Computer Monitor where the chromosomes spread in the metaphase plate (on the left) are lined up in a karyogram (on the right). Photograph taken by the author with permission.

Microphotography—i.e. photographs taken with a microscope—has always been the traditional method of chromosome visualization. Even if it is still possible to see a 35 mm camera mounted on some old microscopes, this technique was discarded in the 1990s, at least in Italian labs. Although a

standard technique since the 1950s, this step has always been a burden in the lengthy and artisanal process of chromosomes visualization. Firstly, this method requires some understanding of the relationship between lens apertures, shutter speeds, and depth of field. Since results could be variable, several separate pictures must be taken to ensure that at least one was successful. Secondly, and most important, chromosomes photographs need to be taken, developed, printed—often in a laboratory dark room or, especially for small labs, in an ordinary photo studio—and materially “cut out” and “pasted” in class order into a papery karyogram.

Nowadays, karyotypes are created on a screen by means of a digital imaging workstation—a computer platform that integrates the microscope with a black-and-white video camera, a digitiser board, and data archive devices. Creating digital images is almost instantaneous and requires little or no photographic expertise. Moreover, in recent years a wide range of software packages especially designed to address the specific requirements of cytogenetics practices, such as Cytovision and CromoWinPlus, have been used to capture, classify, and enhance images. However, what happens in everyday activities is not that simple. While image acquisition is easy and effective, chromosome classification has a very poor success rate for the generation of karyotypes, even with so-called last-generation “fully automated digital systems.” Not surprisingly, these features are generally bypassed or used just to make a “first pass” at arranging chromosomes in pairs, which are then reclassified by individually dragging and dropping them to their proper place. By replacing the classical toolbox of film, photographic paper, developer, scissor, glue, and the bench with a few easy devices like the digitiser board, keyboard, and mouse, the digital system “can be seen as one of the most important developments in automation of the cytogenetics laboratory,” as an authoritative cytogenetics handbook neatly points out (Gersen and Downey 2005, 120).

The dramatic reduction of time and cost that these technologies allow is universally deemed an improvement and have assured them an increasing popularity. Their other second noteworthy feature, namely the capacity to expand chromosome visibility and analysability, is instead more controversial. Image enhancement features have rapidly evolved in the last years and now include features to eliminate unwanted cellular material in the background, to adjust brightness, contrast and colour, and even straightening, scaling, or aligning chromosomes in order to allow direct comparison among chromosomes of different cells. As a marketing manager for several genetic image-analysis products puts it clearly in an article addressed to biologists, the novelty of these new technologies should not be reduced to an increase in speed of results, but should also be seen as a substantial change in the quality of images, accuracy and presentation (Gee 2001). Digital imaging platforms aim not just at automating cytogenetics procedures, but at something more: by intervening in the actual

analysis, they try to *provide a perceptual field alternative to that of the microscope*. This change at the same time fascinates and troubles biologists. Drawing on the distinctive ethnomethodological meaning of “reflexivity” (Garfinkel 1967), we explore how the different uses of a new technology of visualization contingently reconfigure both the heterogeneous social and material visual fields in which representations are composed and used, and the theories of representation inextricably tied to them.

### III. PRACTICES, ORGANIZATION, EPISTEMOLOGY, AND AESTHETICS OF THE INSTRUMENTAL VISUAL FIELDS OF ACTIVITY

The activity of scrutinizing chromosomes can vary considerably. Peering into a microscope inhibits head and body movements, as well as any utterances. Not only is the microscopist immobilized and silent, but the visual field is also static, only allowing one to operate the focusing knob in order to emphasize the tridimensionality of chromosomes, which, like sticks, have a cylindrical form. In contrast, the digital visual field provided by the computer screen does not compel the observer and the object to be frozen. Once cells have been selected (by the microscope) and captured, digital systems require different representational practices, which consist in using a computer mouse to alter contrast, brightness, and straightening, to zoom, and to compare chromosomes. Usually, those who privilege on-screen analyses also develop more advanced computer literacy, and tend to manually modify the adjustment acquisition parameters—i.e. gain, off-set, and exposure. In addition, the computer displays the image on a large flat surface available to more than one person simultaneously, allowing biologists to point out interesting features to each other. The computer screen thus serves as a dynamic, public space where multiple viewpoints can be reconciled at the same time and where controversial or curious cases can be shared more easily with colleagues or modified collectively (e.g. “try to increase contrast”). Several works on digital visibility have explored interactivity in the process of visualization and viewing that was introduced first and foremost by the intersubjective space provided by computer screens. During my ethnographic experience, I myself have benefited from this opportunity, which has unquestionably enriched my capacity to be acquainted with the subtle processes of visualization. In fact, I observed cytogeneticists’ activities *only* when they were working on-screen, while I have second-hand information regarding the interaction between scientists and the microscope: in the best of situations they explained to me what they were doing with an instrumental field that was inaccessible to me.<sup>3</sup>

In any case, both microscopes and digital platforms provide two instrumental

<sup>3</sup> In a pre-digital era, large laboratories were equipped with multifocal microscopes that were used to teach students how to peer into the microscope.



perceptual fields, which are here understood as intersubjective sites of the organization of the material arrangement of workplace. For example, in labs where the primacy of the microscope over the computer is set as a general rule, all practitioners usually choose to stain chromosomes with a fluorescence dye, called “quinacrine mustard,” which is more visible in a darkened room. Therefore, the environment of these labs is impressively dim and silent, totally different from the brighter and more communicative (and noisy) workplace of the labs that use “Giemsha,” another dye generally associated with digital imaging technologies. The visual space that these instruments of visualization allow—or, in Gibson’s terms, “afford”—defines and is defined by the coherent and heterogeneous texture of embodied practices, procedures, materials, (reagents, biosample etc.) and organization that constitutes the social and material order of a laboratory. These different spaces are unquestionably divergent, however; even if they collide, they can also coexist without any frictions.

According to my interviewees, this was particularly true in the early days of the introduction of digital imaging technologies, when these two perceptual spaces were used for different tasks. Each cytogenetic diagnostic referral is constituted of two kinds of reporting data or, in Latour’s (1990) terms, “inscriptions.” The first is a brief textual code consisting in the number of chromosomes, the sexual chromosomes and, if present, the anomaly. For example, a female human without genetic aberration is reported as “46, XX”, a man with a third anomalous chromosome 21 (the Down syndrome) as “47, XY +21”. The second kind of inscription is the karyotype: in a single visual field, it juxtaposes the actual chromosomes obtained in the lab with a bio-sample in alphanumeric order (from 1 to 23 plus X and Y) for the rigorous, replicable standard classification (see Figure 1). These are the final results of two different tasks. Basically, codes are produced by an actual analyses of the chromosomes, while karyotypes are prepared (usually *after* the accomplishment of the interpretative work) to be kept in the archive to guarantee the quality and correctness of analysis. In clinical cytogenetics labs, visual displays are more than pictorial illustrations for textual inscriptions; in fact, they are the most reliable evidence in case of a lawsuit against the medical lab.

This distinction is also reflected in the requirements of scientific-professional guidelines. For example, according to the Italian Society of Human Genetics (Sigu 2007, 7), for a prenatal diagnosis using amniotic fluid a minimum of 16 cells should be fully analyzed, and for only three of them (usually “the nicest” ones) the karyogram should be prepared. For some years this division of labour was congruent with a division of instruments uses. The analyses of metaphases were usually done by microscope, and definitely not by importing all images on digital systems, which, instead, were used only to produce more easily and promptly the karyotypes to be archived. As a cytogeneticist working in a Department on Human Genetics of a University hospital described it:

In our lab we have chosen to not intervene on chromosome... with computer, I mean. When we import images on computer, in some cases, we regulate contrast, brightness and so forth. However, the less artifice is the better. It is like removing red-eyes with Photoshop.

This statement of one of my informants, an experienced cytogeneticist who we will call Dr. Variale, is representative of Italian cytogeneticists. Even if certain labs that are more open to digital technologies exist, the extension of digital systems is discarded by many cytogeneticists as a dangerous shortcut—an easier and faster, but less accurate, manner of performing analysis. Since performing on-screen analyses is less demanding, and adjusting karyotypes can be reassuring, the use of computer-assisted systems is considered by these labs as a sort of cheating, and likened to photoshopping. According to this approach, microscopes are considered a more reliable source of data, while digital systems are considered more powerful systems that can be exploited for their capacity to rearrange and replicate images. The use of the computer is thus limited to the production of visual displays to be archived. Managing the instrumental visual fields of activity implies not only an organization of the practices, bodies, workplace arrangements, and materials, but also different constructions of representational truth, as the following words of a cytogenetics laboratory director clearly show:

It seems to me that, when you straighten chromosomes, their bands are modified. They are all prettier but, in my opinion, some bands are reduced and others enlarged. I never do it. [...] Actually, these chromosomes are more photogenic [*laughs*]. They are glossy [*patinati*] chromosomes, but they don't convince me.

In this quotation two different interwoven arguments are clearly distinguishable. First, the manipulability and plasticity of digital systems raise an epistemological question. These technologies are considered to be both an opportunity to increase the quality of an image and a potential source of distortions and artefacts that tends to simplify and to flatten images. On the contrary, focusing in and out while peering into microscope is perceived as a method that is more faithful to reality. This concern becomes particularly urgent in controversial cases, when one needs to decide in which instrumental visual field an unclear chromosomal arrangement is to be solved, and to which extent it is possible to alter the gradation of greys in order to bring out a banding pattern. According to the words of the director, only one instrument has “the last word,” and that depends on the epistemological primacy—either of the microscope or of the digital system—assumed by a cytogeneticist in her own work routines. A second element, which is well illustrated in both quotations, is

a question of aesthetic preferences. In this regard, Dr. Variale's lab motto—"the less artifice the better"—is similar to the lab chief's suspicion towards "glossy" and "more photogenic" chromosomes. These aesthetic dispositions result from contrasting "colour enhanced" and "straightened" digital chromosomes with the more nuanced, tridimensional chromosomes of microscope, which are perceived as more realistic.

Again, we can see a correspondence between the assumptions of the theories of representation embedded in these practices and the division of labour. Organizational analysis raises epistemological questions, and karyotyping practices raise aesthetic preferences. Even if there is a connection between the two options, a "realist" epistemology does not necessarily entail a "hyper-realistic" aesthetics. For example, in Dr. Variale's lab—where, as we have already seen, only a mild visual enhancement of chromosomes is allowed—the most uncertain and controversial cases are solved by "playing with the computer." However, as Dr. Variale specifies, the only biologist allowed to use the computer in this manner is the director himself. Diffidence towards the visual rendering of features of imaging software is inevitably associated with a "hierarchical" organization of their use.

#### IV. CONCLUSIONS

In a recent review essay on practices of seeing, Charles Goodwin pointed out that after the deep influence of ethnomethodology on representations in scientific practice, "research in science studies has investigated the *images* produced by scientists and the way they visually and mathematically structure the world that is the focus on their inquiry" (Goodwin 2000, 160). His main analytic concern is with the absence of materiality and the viewing bodies, which in fact play a major role in the process of visualization. Marko Monteiro (2010b) has advanced this criticism of the limitations of understandings of scientific representations by pointing out the crucial role that is played by digital images in the process of scientific visualization—or "digital objects," as they are called to emphasize their social materiality deployed in their interactions with scientists. As we have already mentioned, cyborg visibility has provided an interesting way to appreciate the role of embodied practices and the relationship between humans and instruments (computers) in the process of visualization (eg. Alač 2008; 2011; Monteiro 2010a; Myers 2008).

This paper insists on the similarly neglected aspect of the materiality of visualization—the instrument of visualization. Even ethnographic studies concerned with how practices, tools, and documents used by scientists make natural phenomena visible have scarcely paid attention to how the perceptual field of an instrument is part and parcel of the heterogeneous and socio-material contexts where representations are produced. On the contrary, the space of action of visualization instruments is a relevant field of activity where specific

practices, materials, organizations, epistemological orientations, and aesthetic preferences are connected with each other. At the same time, visualization instruments are usually elements that are taken for granted, considered to be part of a black box that is difficult to open. A scientific field like cytogenetics, where two different instruments are used simultaneously to visualize the same objects (chromosomes), gives us the opportunity to single out the specificities of microscope and digital system through their either divergent—even conflicting—or complementary relationship. In the current situation of technological change, the different and sometimes competing uses of these instruments become a source of reflexivity. The changes triggered by a process of innovation offer an ideal situation to observe the ways in which the varied courses of representational activities become heterogeneously ordered, accountable, and natural. The same materiality of chromosomes is shaped through these processes as the result of interactions with these new technologies and the new visual practices. Both optical and digital instruments take part in contingent and yet meaningful ways in the practical organization of work, division of labour, arrangement of workplaces, professional hierarchy, degrees of representational truth, and resemblance to nature. The contemplative relationship between observer and research object embedded in the microscope can be seen either as a resource or a fallacy, and it is thus considered contingently. Accordingly, this analytical perspective moves opticism and digitality from the unavoidable trajectory of technological innovation to the configuration that their related and juxtaposed visual activity fields assume in relation to each other in concrete activities. For the study of scientific visualization, digital technologies are thus interesting not only as cutting-edge technological innovations with which to represent and intervene in reality, but also as technologies with complex, concrete, and contingent interconnections with older technologies.

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