Kristóf Nyíri

From Texts to Pictures: The New Unity of Science

Changes in communication technologies have over and over again in the course of history resulted in changes in the nature of scientific thought. In particular, the printing press, in the specific European context, played a central role in giving rise to the development of modern science. Printed scientific texts, to a greater or lesser degree, have been regularly accompanied by diagrams and pictures; however, some spectacular exceptions notwithstanding, the text dominated the image. And while the logic of the linear text was conducive to strict reasoning, it also fostered excessive specialization and compartmentalization within science. The philosopher and sociologist Otto Neurath, a leading member of the Vienna Circle, was among the first to suggest that, with the help of a pictorial language, a new unity within science could be achieved. In the present work-in-progress draft I will attempt to show how the emergence of computer graphics and multimedia computer networking might lead to a fulfilment of Neurath's vision.

I am drawing on two previous talks of mine. In the first one I ventured to suggest that "the ideal of unified knowledge had been a genuine one during [a] fleeting moment of history, the sixteenth and seventeenth centuries. Before that, it was unfounded; and after that, unattainable."[1] With the coming of the digital age however, I noted, we now observe

> possibilities inherent in electronically mediated communication which might operate against the trend of fragmentation[:] ... Complex information which when cast into the mould of the linear text becomes impossible to grasp in a comprehensive formula, might easily be taken in at a glance or absorbed in a single harmony when presented in the media of images and sounds. Secondly, printed texts, when supported by electron-

[1] "Electronic Networking and the Unity of Knowledge", in Stephanie Kenna and Seamus Ross (eds.), *Networking in the Humanities* (Proceedings of the Second Conference on Scholarship and Technology in the Humanities, held at Elvetham Hall, Hampshire, UK, 13–16 April, 1994), London: Bowker-Saur, 1995, p. 260.

> ic versions of the same, can be studied more thoroughly and comprehensively than when available on paper only. When hypertext, multimedia, and networking are *added* to the printed book, the possibilities to achieve a kind of overview of knowledge, to maintain its *relative* unity, are heightened.[2]

By the time of the second talk, presented at a conference some two years ago,[3] I was putting rather less emphasis on the printed text. I offered

> three arguments. All three are bound up with the once more strengthening continuity between theory and practice at this dawn of a network digital culture. First: when the relative weight of applied research as compared to basic research is growing, the experience of coherence in everyday life overrides the image of fragmented scientific specialities. Secondly: in the medium of the computer abstract calculation and concrete experiment meet; and since in the virtual space all skills tend to become similar in type, they are less likely to create a distance between particular theories. ... Thirdly: as a consequence of digitalization, text and picture come closer to each other. Pictures can show what texts can only describe; pictures are relatively independent of their linguistic-conceptual surroundings; and pictures ... are better at conveying practical knowledge than are texts. This state of affairs, coupled with the fact that in the medium of the internet disciplinary isolation is difficult to maintain, renders the perspective of a unified science rather less illusive than it was some decades ago.[4]

Let me here recapitulate the arguments of these two talks, adding a number of further strands. I will begin with some observations on the place of pictorial communication in the project of unified science as envisaged by Neurath.

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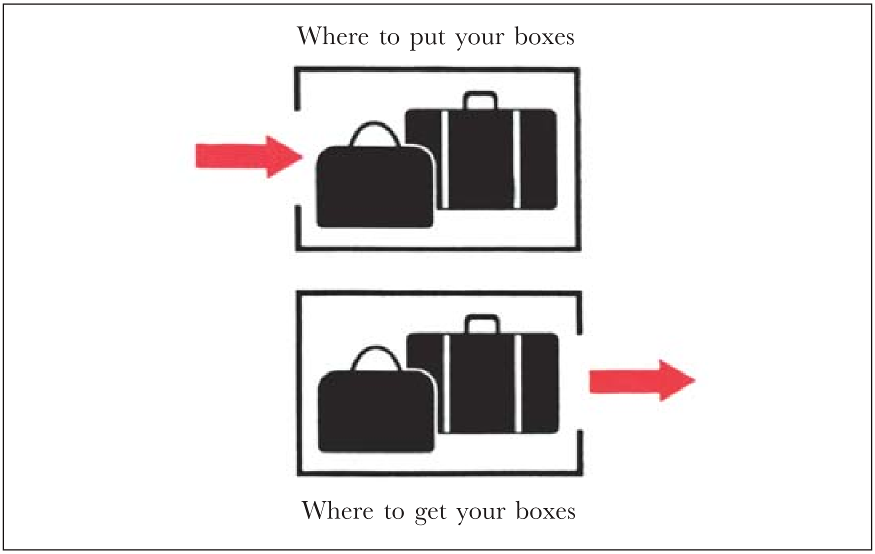
[2] *Ibid.*, pp. 275 f.

[3] *Information Society, Interdisciplinarity, and the Future of the Humanities*, conference held at the Institute for Philosophical Research of the Hungarian Academy of Sciences, Budapest, Nov. 4, 2000, www.fil.hu/highlights/tudnap_2000.htm.

[4] "Words, Pictures, and the Unity of Knowledge" (2000), www.fil.hu/highlights/nyiri_presentation.htm

Neurath's Encyclopedia

From the 1920s to the 1940s, first in Vienna, later in The Hague and finally in London, Neurath and his associates worked on the creation of an iconic language which by the mid-1930s he was calling the "International System Of Typographic Picture Education", abbreviated as *isotype*.[5] The icons elaborated within the framework of the isotype program eventually came to serve as models for those international picture signs we today encounter at airports and railway stations. However,



(From Neurath, *International Picture Language*)

Neurath had originally pursued a much more ambitious aim: that of systematic scientific visualization. In the prefatory note to his *International Picture Language* he speaks about "turning the statements of science into pictures",[6] and envisages producing not just "a teaching book on a special branch of knowledge", but indeed an *encyclopedia*. "The ISOTYPE picture language", he writes, "would be of use as a helping language in an inter-

[5] I have described this system briefly in my paper "Pictorial Meaning and Mobile Communication", in: Kristóf Nyíri (ed)., *Mobile Communication: Essays on Cognition and Community*, Vienna: Passagen Verlag, 2003, pp. 176 f.

[6] Otto Neurath, *International Picture Language*, London: 1936, repr. University of Reading: Dept. of Typography & Graphic Communication, 1980, p. 8.

national encyclopaedia of common knowledge. Such an encyclopaedia will be the work of our time."[7] As he puts it later in the book, in the section "From Designs in Stone and the Orbis Pictus to the Isotype Encyclopaedia":

> In present Europe the idea of picture education is not more than 300 years old. Before that there was not very much connection between words and pictures. The books and the thoughts of those times had little to do with experience... In later times the relation between words and pictures became clearer, in connection with the development of science. – The Orbis Pictus of Comenius gives pictures for a great number of words and names in different languages. ... The invention of printing in black and white gave a new impulse to every sort of writing and designing for a wide public. ... One special branch of work was the making of pictures of military stations and of fights, in which the order of military units is designed in a way which is very like the ISOTYPE system. ... In the writings of Leibniz we come across the idea that picture-making is to be done with the help of science. His desire was to make an "atlas universalis" in connection with an encyclopaedia. The French encyclopaedia gave a great amount of material and a great number of pictures, but there was only a loose connection between them.[8]

And here then follows the crucial passage:

> At this time the idea of an international encyclopaedia is coming once more to the front. ... The encyclopaedia will make use of one language for all sciences, it puts out all feeling – all words for right and wrong – from the account of science, it will have as little as possible to do with any words or any signs which are not clear, it will make use of one picture language. The purpose of this new encyclopaedia, which is only an addition to other encyclopaedias, is to give all men a common starting-point of knowledge, to make one united science, forming a connection between the special sciences and putting together the work of different nations, to give simple and clear accounts of everything as a solid base for our thoughts and our acts, and to make us fully conscious of conditions in which we are living. This encyclopaedia will be all the time in the process of growth, like society, science, and language themselves. What the science of reasoning has done to make possible such a uniting

[7] *Ibid.*, p. 65.
[8] *Ibid.*, pp. 106 ff.

of the sciences and to give one word language to all the special sciences, the ISOTYPE system has done to make possible one language of pictures which will give the same sort of help to the eye for all the special sciences and for persons of all nations.[9]

Old military picture

(From Neurath, *International Picture Language*)

[9] *Ibid.*, pp. 110 f.

The rudimentary technologies of design and production Neurath and his team had at their disposal obviously precluded the accomplishment of such lofty aims. The glaring disparity between intention and achievement should not however blind us to the fact that from a philosophical point of view Neurath's program was not entirely outlandish; certainly it was well embedded in Neurath's specific version of Vienna Circle logical empiricism. The book *International Picture Language* was written in "Basic English", a radically impoverished version of English, devised by C. K. Ogden, the translator of Wittgenstein's *Tractatus*, a work itself very much preoccupied with the simplicity and the pictorial aspects of language. Now it is significant that Neurath sees a fundamental similarity between iconic communication on the one hand and Basic English on the other. As he puts it:

> the uses of a picture language are much more limited than those of normal languages. It has no qualities for the purpose of exchanging views, of giving signs of feeling, orders, etc. It is in no competition with the normal languages; it is a help inside its narrow limits. But in the same way as Basic English is an education in clear thought – because the use of statements without sense is forced upon us less by Basic than by the normal languages, which are full of words without sense (for science) – so picture language is an education in clear thought – by reason of its limits.[10]

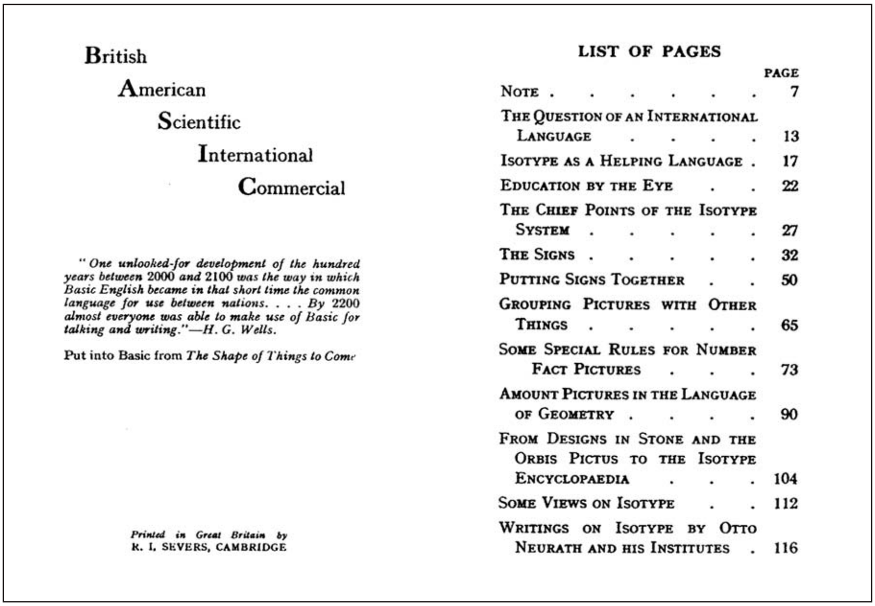
We can compare the message of this paragraph with three other important propositions by Neurath. First, from his classic paper "Protokollsätze",[11] where he says: "Einstein's theories are expressible (somehow) in the language of the Bantus – but not those of Heidegger, unless linguistic abuses to which the German lends itself are introduced into Bantu."[12] Second, an aphorism from his *Einheitswissenschaft und Psychologie*, written at about the same time: "Metaphysical terms divide – scientific terms connect."[13] Third, a sentence, in the awkward style of Basic English, from *International Picture Language*: "Words make division, pictures make connec-

[10] *Ibid.*, pp. 20 ff.

[11] Published in the Vienna Circle journal *Erkenntnis* in 1932/33.

[12] Here quoted from the English translation ("Protocol Sentences") in A. J. Ayer (ed.), *Logical Positivism,* Glencoe, IL: The Free Press, 1959, p. 200.

[13] "Metaphysische Termini trennen – wissenschaftliche Termini verbinden" (Otto Neurath, *Einheitswissenschaft und Psychologie*, Vienna: Gerold & Co., 1933, repr. in Neurath, *Gesammelte philosophische und methodologische Schriften*, ed. by Rudolf Haller and Heiner Rutte, Vienna: Hölder-Pichler-Tempsky, 1981, vol. 2, p. 610.)



British
American
Scientific
International
Commercial

" One unlooked-for development of the hundred years between 2000 and 2100 was the way in which Basic English became in that short time the common language for use between nations. . . . By 2200 almost everyone was able to make use of Basic for talking and writing."—H. G. Wells.

Put into Basic from *The Shape of Things to Come*

Printed in Great Britain by
R. I. SEVERS, CAMBRIDGE

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tion." Neurath's message is unambiguous: clear thoughts can be expressed in simple language, and simple language can be translated into pictures. Unified science becomes possible once the language of science is purged of metaphysical terms; and anything that needs to be expressed within the framework of unified science can be communicated by a pictorial language.

In 1938 there appeared the first issue of the *International Encyclopedia of Unified Science*, edited by Neurath, Rudolf Carnap, and Charles Morris. The introductory essay – "Unified Science as Encyclopedic Integration" – was written by Neurath. It contained only a brief allusion to the idea of scientific visualization.[14] Important from the point of view of the present draft is however an essay by Dewey in the same issue. As Dewey here wrote:

> the scientific method is not confined to those who are scientists. The body of knowledge and ideas which is the product of the work of the

[14] "It is hoped", remarked Neurath, "that an *Atlas* can be worked out as an *Isotype Thesaurus* showing important facts by means of unified visual aids." (*International Encyclopedia of Unified Science*, vol. I, no. 1, Chicago: The University of Chicago Press, 1938, p. 25. An endnote with a reference to Neurath's book *International Picture Language* occurs on p. 27.)

> latter is the fruit of a method which is followed by the wider body of persons who deal intelligently and openly with the objects and energies of the common environment. In its specialized sense, science is an elaboration, often a highly technical one, of everyday operations. In spite of the technicality of its language and procedures, its genuine meaning can be understood only if its connection with attitudes and procedures which are capable of being used by all persons who act intelligently is borne in mind.[15]

To which he added:

> Few would rule engineers out from the scientific domain, and those few would rest their case upon a highly dubious distinction between something called "pure" science and something else called "applied" science. ... Pure science does not apply itself automatically; application takes place through use of methods which it is arbitrary to distinguish from those employed in the laboratory or the observatory. And if the engineer is mentioned, it is because, once he is admitted, we cannot exclude the farmer, the mechanic, and the chauffeur, as far as these men do what they have to do with intelligent choice of means and with intelligent adaptation of means to ends, instead of in dependence upon routine and guesswork.[16]

Texts and the Fragmentation of Science

In my talk "Electronic Networking and the Unity of Knowledge", some passages of which I will more or less verbatim repeat in the present section,[17] I recalled that as long as books were copied manually, i. e. before the age of the printed press, the overall coherence of the existing literature had been inconceivable, since copies even of the same work increasingly differed from each other. Texts became interspersed by com-

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[15] John Dewey, "Unity of Science as a Social Problem", *ibid.*, pp. 29 f. – One did not have to be a pragmatist philosopher to subscribe to the idea that scientific thinking is continuous with everyday thinking. In his book *Imagery in Scientific Thought: Creating 20th-Century Physics* Arthur I. Miller quotes Albert Einstein as writing (in 1934) that "[t]he whole of science is nothing more than a refinement of everyday thinking. It is for this reason that the critical thinking of the physicist cannot possibly be restricted to the examination of concepts of his own specific field. He cannot proceed without considering critically a much more difficult problem, the problem of analyzing the nature of everyday thinking" (Boston: Birkhäuser, 1984, p. 13).

[16] Dewey, *op. cit.*, p. 30.

[17] Cf. Stephanie Kenna and Seamus Ross (eds.), *Networking in the Humanities*, pp. 259 ff.

ments if copied by an expert scholar, impaired by mistakes if copied by an unqualified clerk. The notion of authorship remained blurred. Printing however could produce thousands of identical copies; mistakes were, with every new edition, progressively eliminated; a community of scholars all over Europe worked on the same texts, gradually establishing a firm framework of categories, names, of historical time and geographical space; descriptions, findings, discoveries could be increasingly compared with each other, maps, diagrams, illustrations, figures and calculations reproduced; the modern ideal of a unified knowledge emerged.

Every age of course does feel the need to bring together the knowledge society possesses. In libraries the documents of learning are physically amassed, permitting, in principle, access to all there is to know. By contrast, encyclopaedias present distilled overall accounts of knowledge. As Bolter observes, these become particularly necessary when there occurs a specific scarcity or a specific abundance of information.[18] The latter was the case in late antiquity, then again after the twelfth century, and of course ever since the invention of book printing. Both libraries and encyclopaedias face the task of not just presenting, but also *organizing* information, a task that becomes increasingly difficult as the complexity of knowledge progresses. Early encyclopaedias could rely on relatively simple, and generally accepted, mythological, theological, or educational patterns. Thus the encyclopaedia of Martianus Capella was organized along the structure of the seven liberal arts; that of Vincent of Beauvais along the six days of creation, a method also adopted by Thomas of Cantimpré, whose *De naturis rerum* served as the basis of Conrad of Megenberg's very successful German translation of 1350, *Buch der Natur*. This is how Conrad begins: "Got beschuof den menschen an dem sehsten tag nâch andern crêatûren und hât in beschaffen alsô, daz seins wesens stük und seins leibes gelider sint gesetzet nâch dem satz der ganzen werlt", man shares certain principles with other creatures, since those principles had already been operative during the earlier phases of creation.[19] Conrad's book treats of everything from the scull of man through edible fruits through signs of pregnancy to precious stones; his descriptions are crude, certainly not sufficient to convey any expertise; the knowledge he offered might have appeared as, but could not possibly have been, a coherent guide to his readers. The belief that there existed a unified

[18] Jay David Bolter, *Writing Space: The Computer, Hypertext, and the History of Writing*, Hillsdale, NJ: Lawrence Erlbaum Associates, 1991, p. 89.

[19] Konrad von Megenberg, *Das Buch der Natur*, ed. by F. Pfeiffer, Stuttgart: Karl Aue, 1861, p.3.

body of knowledge, some of it written, as the metaphor had it, in the books of men, and all of it engraved in the book of God, of Creation, of Nature, was vivid all through the Middle Ages, and was merely reformulated by Descartes and Leibniz in the seventeenth century and Bolzano in the nineteenth; however, the conditions to build up a unified framework of ideas were simply not given before the age of the printed book. And by the eighteenth century it became clear to most that the rapidly expanding world of knowledge could actually not be fitted into that framework.[20] Bacon, in the Second Book of his *Advancement of Learning* (1605), could confidently survey and systematize the existing state of knowledge, pointing out gaps and suggesting ways to fill them in. Less than a century later Fontenelle announces the publication of research results by the French Academy saying that those consist of "details detached from,

[20] Meyrowitz proposes a different explanation for the fact that "the spread of print supports compartmentalization and specialization". Printing has led to the emergence of the age-graded school. But "distinctions in reading abilities", the "different levels of reading complexity", offer "a seemingly natural means of segmenting information – and people. All fields begin to develop 'introductory' texts that must be read before one can go on to 'advanced' texts. Identities splinter into a multitude of separate spheres based on distinct specialties and mastery of field-specific stages of literacy. The new grading of texts serves as a barrier to straying from one field into another. Crossing into a new field demands that one must bear the embarrassement of starting again as a novice and slowly climbing a new ladder of printed knowledge. This contrasts markedly with the oral and scribal approach, which is inherently interdisciplinary and non-graded." (Joshua Meyrowitz, "Medium Theory", in David Crowley and David Mitchell [eds.], *Communication Theory Today*, Stanford, CA: Stanford University Press, 1994, p. 65.) The assumption of an inherently interdisciplinary scribal culture is not universally accepted. This is how Elizabeth Eisenstein sees the matter: "during the age of scribes ... opportunities for cross-cultural interchange were necessarily restricted and limited. An apprentice learning to wield the tools of the surgeon–barber, and a university student transcribing passages from Latin translations of Greek and Arabic medical texts were acquiring skills that were conveyed by entirely separate 'transmission belts'. Even within the university itself, the conditions of scribal culture prevented an interchange between disciplines that now seem to be closely related: astronomy and physics, for example. ... The charts and tables of the *Almagest* were preserved ... by a select group of professional astronomers, from which Copernicus ultimately emerged. Records containing precise computations required special training for copyists, close supervision of scriptoria, careful custody of relevant texts and detailed instruction in how to use them. Mastery of planetary astronomy under such conditions was almost bound to isolate this discipline from other branches of learning." (Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe*, Cambridge: Cambridge University Press, 1979, vol. I, pp. 270 f.)

and independent of, each other". But he adds that those results might one day add up to a whole. "Plusieurs vérités séparées", he writes,

> dès qu'elles sont en assez grand nombre, offrent si vivement á l'esprit leurs rapports et leur mutuelle dépendance, qu'il semble qu'après avoir été détachées par une espèce de violence les unes d'avec les autres, elles cherchent naturellement à se réunir.[21]

Another fifty years go by, and d'Alembert, though very much inspired by Bacon, rejects the idea of a definitive synthesis of all sciences. As he writes:

> Le système général des sciences et des arts est une espèce de labyrinthe, de chemin tortueux où l'esprit s'engage sans trop connaître la route qu'il doit tenir.

Now d'Alembert points out that matters are different when it comes to the project of an encyclopaedic ordering of knowledge:

> Ce dernier consiste à les rassambler dans le plus petit espace possible, et à placer, pour ainsi dire, le philosoph au-dessus de ce vaste labyrinthe, dans un point de vue fort élevé d'où il puisse apercevoir à la fois les sciences et les arts principaux; voir d'un coup d'œil... C'est une espèce de mappemonde...

However, d'Alembert goes on:

> On peut ... imaginer autant des sytèmes différents de la connaissance humaine que des mappemondes de différentes projections; et chacun de ces systèmes pourra même avoir, à l'exclusion des autres, quelque avantage particulier.[22]

D'Alembert does not, any more, believe in the possibility of a unified and unique description of our knowledge of the world. But he has no reason to doubt the givenness and unity of the world itself. The world is an ordered whole of causes and effects, governed by immutable laws. The book of nature is there – even if it cannot be once and for all translated into books of men.

[21] Bernard Le Bovier de Fontenelle, *Textes choisis*, Paris: Editions sociales, 1966, pp. 278 f.

[22] Jean Le Rond d'Alembert, *Discours préliminaire de l'Encyclopédie* (1751), Paris: 1893, pp. 66 ff.

To register the impossibility of achieving an overview of the world of texts means to lose the ground for a belief in the unity and coherence of that world. It means renouncing faith in a single correct perspective; it means accepting the legitimacy of holding multiple points of view with respect to the same subject, of letting context take precedence over denotation; ultimately it means giving up the idea of definite meanings and objective truths, indeed giving up the idea of the unity and givenness of the world itself.[23] Towards the end of the nineteenth century this is the stance Nietzsche takes – I deliberately avoid the term "position" in the case of a philosopher whose style so intensely suggests the determination not to have a position. Nietzsche not only rejects bookishness – "we moderns" he says, are but "walking encyclopaedias"[24] – he also quite consciously eludes the magic of, and turns against, the *objektive Schriftsprache*, "objective written language".[25] And less then a hundred years after Nietzsche, by the mid-twentieth century, it has become a philosophically admissible thesis that the world of knowledge was too immense to permit any kind of overall grasp, and that, consequently, the supposition of a single reality was meaningless. Thomas Kuhn's very influential book *The Structure of Scientific Revolutions*, published in 1962, ostensibly dealt with the incommensurability of successive scientific paradigms, but it was understood to imply a thesis both diachronic and synchronic to the effect that divergent scientific theories should be interpreted as constructions of different worlds of objects, rather than as competing explanations of one and the same world. Five years earlier Gaëtan Picon, in the introductory essay to the popular collection he edited, *Panorama des idées contemporaines*, a collection immediately translated into several languages, registered a feeling of disorientation effected on the one hand by the idea of indeterminacy in quantum mechanics, and on the other hand, again, by the "spécialisation croissante" – the "growing specialization". This, as he put it, "éloigne de plus en plus de toute image ordonnée du réel. Au monde succèdent les mondes". "[D]écentré", wrote Picon, "le système de la connaissance",

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[23] The inference from the loss of truth to the loss of faith in the givenness of the world is, strictly speaking, not stringent; but it is the usual move in philosophy. Thus Edmund Husserl could write (*Logische Untersuchungen*, vol. I, Halle: Max Niemeyer, 1900, p. 121): "Die Relativität der Wahrheit zieht die Relativität der Weltexistenz nach sich", *the relativity of truth leads to the relativity of the existence of the world.*

[24] Friedrich Nietzsche, *Sämtliche Werke: Kritische Studienausgabe*, dtv – de Gruyter, 1980, vol. 1, pp. 273 f.

[25] *Ibid.*, vol. 7, p. 48. The definitive monograph on Nietzsche as a philosopher of the orality–literacy tension is Rudolf Fietz, *Medienphilosophie: Musik, Sprache und Schrift bei Friedrich Nietzsche*, Würzburg: Verlag Königshausen & Neumann, 1992.

and: "Le monde a éclaté en mondes irréductibiles, qui vivent d'une coexistence sans communication ni hiérarchie."[26] When Nelson Goodman published his *Ways of Worldmaking* in 1978, he could speak of a "movement" "from unique truth and a world fixed and found" to a "diversity" of truths and a "multiplicity of worlds", and refer to Ernst Cassirer's work from the twenties and thirties as one of the earlier stages of that movement.

A work reassessing the Kuhnian notion of a paradigm in view of the current proliferation of scientific fields was Diana Crane's book *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*, published in 1972. As she put it:

> An idea that is rejected in one specialty may be accepted in another. ... The existence of hundreds of fields, growing and declining, linked to some extent by concepts that have proved useful in several areas and with no clear-cut boundaries between them, permits both rapid diffusion of ideas and also the coexistence of mutually incompatible ideas if applied to different research topics."[27]

The term "invisible colleges" in Crane's book – a term that first seems to occur in the Boyle–Hartlib correspondence – refers to informal groups of scientific elites through whom the communication of information both within a field and across fields is directed. The members of research areas, Crane found, "were not so much linked to each other directly but were linked to each other indirectly" through the "highly influential members" belonging to the elite. These prestigious figures "were surrounded individually by subgroups of scientists who looked to them for information. They in turn communicated intensively with one another". As Crane, quoting another researcher, writes: it is through "the central scientists" that "information may be transferred to all other scientists in the network".[28] The reference here is of course to social, not to electronic networks – what from our present point of view makes Crane so interesting is that the findings she accepts immediately invite a reformulation of her questions in terms of today's networking practices. Is it still the case, we will have to ask, that members of the scientific elite occupy a central place in the channelling of information? The question was answered in

[26] Paris: 1957, rev. ed. Paris: Gallimard, 1968, pp. 17 f. and 28.
[27] Chicago: University of Chicago Press, 1972, p. 39.
[28] *Ibid.*, pp. 49 and 52 f.

the affirmative both by László Babai in 1990,[29] and by Albert-László Barabási in his recent book.[30]

Pictures in a Knowable World

The notion of a comprehensive unified knowledge must be found illusive once one realizes that any branch of knowledge is invariably embedded in particular practices,[31] and that therefore, as Gordon Baker argues interpreting Wittgenstein, a single perspicuous representation of different language games is not conceivable,[32] or, to put the same point differently, that a comprehensive and unified knowledge could not be *subjectively represented* – no mind could serve as its focus, no person could embody the sum of necessary skills. However, let me make two points. First – recall Neurath's arguments – pictures might sometimes succeed where texts fail. Pictures, especially animated pictures – by themselves, or in combination with words – can quite effectively convey practical knowledge.[33] Also, pictures can summarize, in a way that can be grasped in a single glance, complex information that may be unintelligible when propositionally expressed.[34] Secondly, the idea of a unified knowledge need not imply the possibility of a single harmonious vision

[29] As Babai writes: "E-mail is capable of creating an *ultracompetitive atmosphere* on a much grander scale than any medium before." An e-mailing of important research results "may give unprecedented information advantage to a well chosen, sizable, and consequently extremely powerful elite group. The group of recipients ... may be fully capable of making rapid advances before others would even find out that something was happening. Although such elite groups belong to the very nature of the hierarchy of scientific research ..., their sheer intellectual force combined with the information advantage makes them look from outside like an impenetrable fortress." (László Babai, "E-mail and the Unexpected Power of Interaction", University of Chicago Technical Report CS 90-15, April 24, 1990, pp. 11 f.)

[30] Albert-László Barabási, *Linked: The New Science of Networks,* Cambridge, MA: Perseus Publishing, 2002, see esp. chapters 6 and 7.

[31] Cf. e.g. the essays by Barry Smith ("Knowing How vs. Knowing What") and by Kristóf Nyíri ("Tradition and Practical Knowledge"), in Nyíri and Smith (eds.), *Practical Knowledge: Outlines of a Theory of Traditions and Skills*, London: Croom Helm, 1988.

[32] Gordon Baker, "*Philosophical Investigations* Section 122: Neglected Aspects", in Robert L. Arrington and Hans-Johann Glock (eds.), *Wittgenstein's* Philosophical Investigations*: Text and Context*, London: Routledge, 1991.

[33] For some references see my paper "Pictorial Meaning and Mobile Communication", in Nyíri (ed)., *Mobile Communication: Essays on Cognition and Community*, pp. 175 f. and 179.

[34] A brilliant book on the subject is Colin Ware, *Information Visualization*, San Francisco: Morgan Kaufmann, 2000. Incidentally, visualization might not be the only non-

of reality. It suffices if we can demonstrate the possibility of *transitions* from one field of knowledge to another; the possibility of conceptual bridges, passages, interactions. And such transitions indeed become easier when word is enhanced by image.

Pictures were the "ordering elements" in Einstein's thinking;[35] for him, verbal processes seem to have played a merely secondary role. As he put it in an oft-quoted passage:

> The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be "voluntarily" reproduced and combined. ... – ... Taken from a psychological viewpoint, this combinatory play seems to be the essential feature in productive thought – before there is any connection with logical construction in words or other kinds of signs which can be communicated to others. – The above-mentioned elements are, in any case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the mentioned associative play is sufficiently established and can be reproduced at will. – According to what has been said, the play with the mentioned elements is aimed to be analogous to certain logical connections one is searching for. – In a stage when words intervene at all, they are, in my case, purely auditive, but they interfere only in a secondary stage as already mentioned.[36]

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verbal means to cope with complexity. As Root-Bernstein observes: "Music ... may be a particularly useful means of training the mind to perceive the ways in which the apparent complexity of an experience (e.g., a Bach fugue or a physiological process) may result from the proper application of simple rules and patterns expressed in tandem." (Robert Scott Root-Bernstein, "Visual Thinking: The Art of Imagining Reality", *Transactions of the American Philosophical Society*, 75 [1985], p. 58.)

[35] "When ... memory-pictures emerge", Einstein wrote in his autobiographical notes, "this is not yet 'thinking'. And when such pictures form series, each member of which calls forth another, this too is not yet 'thinking'. When, however, a certain picture turns up in many such series, then ... it becomes an ordering element for such series, in that it connects series which in themselves are unconnected. Such an element becomes an instrument, a concept." (Quoted by Arthur I. Miller, *Imagery in Scientific Thought*, pp. 43 f.)

[36] Quoted by Arthur Koestler, *The Act of Creation*, London: Hutchinson, 1964, pp. 171 f. Koestler is quoting from Jacques Hadamard, *The Psychology of Invention in the Mathematical Field*, Princeton University Press, 1949. The integrative role of motor – "muscular" – images is emphasized by Allan Paivio, in his *Imagery and Verbal Processes*. As he puts it: "a motor component (implicit or explicit) appears to be generally characteristic of images

Visual thinking, working with mental images, has obviously played a fundamental role throughout our history. However, this mode of thinking was for a long time hampered by the absence of physical counterparts – a problem which was solved only in the fifteenth century with the invention of the new technology of picture printing.[37] After 1400, and most notably in the sixteenth and early seventeenth centuries, scientific – or proto-scientific – visualization became widespread. The sixteenth century, as Freedberg puts it, was "the first great age of visual encyclopedias".[38] And the year 1543 witnessed the publication of Copernicus' *De revolutionibus* and Vesalius' *De humani corporis fabrica*, both making decisive use of pictures – indeed there is even a common logic to the way the two books employ them. James Franklin refers to Tartaglia's Italian Euclid of 1543 to introduce the argument. The latter work, he writes, "is geometry in the narrow sense. But the big two books of 1543 ... are also geometry, if a slightly wider sense of the term is allowed. ... the three books share more than just pictures... ... The point of Euclid is to *reason* about the diagrams, and expose the necessary interrelations of the spatial parts. So it is with Copernicus and Vesalius."[39]

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of movement, and of the transformations involved in the generation of an integrated figural image or the solution of more complex problems requiring visual thinking. The motor component somehow facilitates the transition from one substantive part of the stream of thought to another." (New York: Holt, Rinehart and Winston, 1971, p. 31.)

[37] I have told the story in some detail in my "Pictorial Meaning and Mobile Communication".

[38] "It is true", Freedberg continues, "that throughout the Middle Ages attempts had indeed been made to assemble compendia of visual information about the world of nature, but they were mostly sporadic and scant in comparison with those that appeared in the wake of the printing revolution. Printing – and the associated arts of woodcut and engraving – enabled the easy reproduction and dissemination of visual information, and students of the natural world were not slow to exploit it." (David Freedberg, *The Eye of the Lynx: Galileo, His Friends, and the Beginnings of Modern Natural History*, Chicago: The University of Chicago Press, 2002, p. 3.)

[39] James Franklin, "Diagrammatic Reasoning and Modelling in the Imagination: The Secret Weapons of the Scientific Revolution", in Guy Freeland and Anthony Corones (eds.), *1543 and All That: Image and Word, Change and Continuity in the Proto-Scientific Revolution*, Dordrecht: Kluwer, 2000, p. 53. Franklin adds: "Galileo's famous saying that the universe is written in the language of mathematics, which when quoted in isolation makes us think, for example, 's = 1/2 gt2', continues in the original, 'its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it'. ... The later phase of the Scientific Revolution is ... algebraic, but the earlier one is diagrammatic" (*ibid.*, pp. 53 f. and 67).

And yet Martin Kemp can, in the same volume as Franklin, convincingly argue for the position that in the sixteenth century there did not emerge "any obvious prospect of a grand, unifying theory based on new forms of representation as corresponding directly to (or precipitating) some great overarching reform of the means of visualization. The relationship between illustration and visualization seems quite different in the various sciences...".[40] Pictures and diagrams could not play a truly unifying role in early-modern science, since the creation of sufficiently sophisticated illustrations was simply not possible with the then available technologies of graphic design. Kemp quotes Copernicus as saying that his problems "are not easily explained adequately with words. Hence they will not be understood when heard ... unless they are also seen by the eyes. Therefore let us draw on a sphere the ecliptic ABCD..." However, as Kemp points out, "the diagrammatic resources available to [Copernicus] were not visually eloquent to anyone who had not already cultivated an ability to visualise in the mind in non-verbal form ... the complex consequences of the relative motions of bodies moving in orbits and epicycles with eccentrics." Actually it was not through the use of printed illustrations, but "through the use of astronomical instruments that the essential mediation between the observed phenomena and their geometrical analysis could be accomplished, and it was through astronomical models that representation could be best achieved for the purposes of instruction".[41]

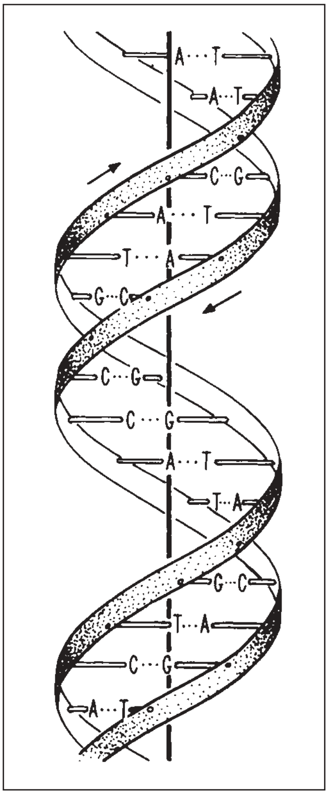
Throughout modernity, pictures and diagrams had to remain subservient to mathematical and verbal argumentation. I agree with Franklin when he says that it is due to "the very recent availibility of computer-intensive visualization tools" that images today are gaining "scientific respectability".[42] Let me here refer to what was undoubtedly the greatest discovery in twentieth-century biochemistry, as also a path-breaking step towards a new interdisciplinarity: the discovery of the double helix by Crick and Watson. This discovery relied quite fundamentally on visualization – initially on visual imagining, and ultimately on 3D-modelling. The modelling of course was done – in 1953 – without the aid of com-

[40] Kemp, "Vision and Visualization in the Illustration of Anatomy and Astronomy from Leonardo to Galileo", in Freeland and Corones (eds.), *op. cit.*, p. 46.

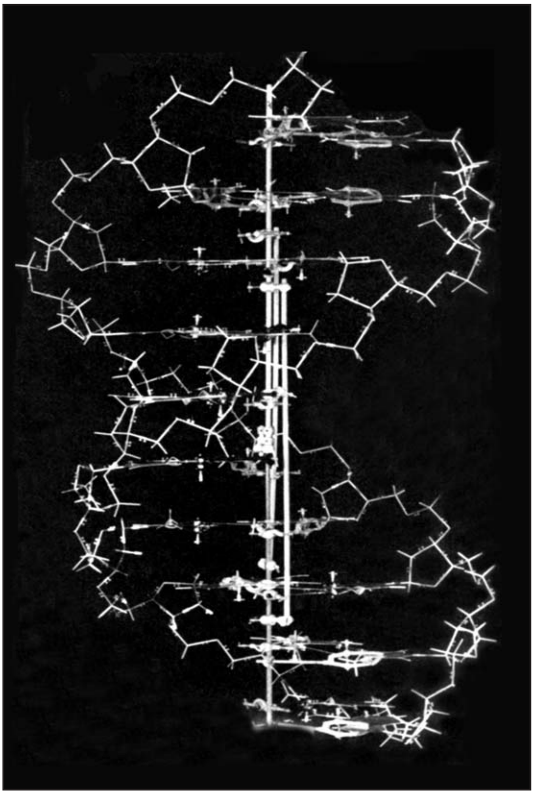
[41] *Ibid.*, pp. 34 f.

[42] Franklin, *op. cit.*, p. 85.

puter graphics. As readers of Watson's *The Double Helix* are aware, this implied that substantial time and energy had to be spent on manual experimenting with, and installing of, bits and pieces of wire and metal.[43]



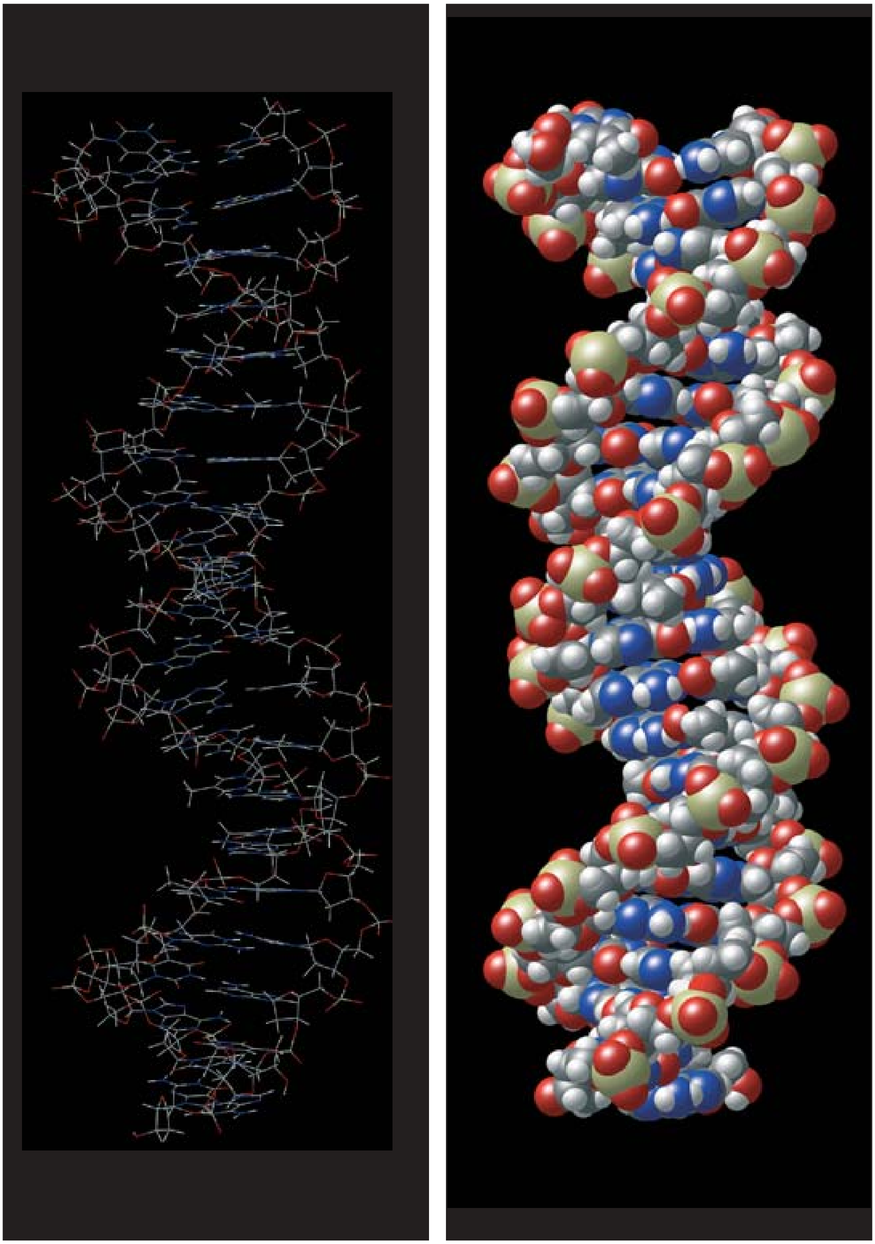
A schematic illustration of the double helix



The original demonstration model of the double helix

(Source: Watson, *The Double Helix*)

[43] James D. Watson, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* (1968), New York: Simon & Schuster, 2001, pp.



Double helix models created by computer graphics

In his book *Image and Logic: A Material Culture of Microphysics* Peter Galison analyzes the relations between contemporary particle physics and image recording.[44] He refers to two competing traditions of instrument making. As he puts it: "One tradition has as its goal the representation of natural processes in all their fullness and complexity – the production of images of such clarity that a single picture can serve as evidence for a new entity or effect. These images are presented, and defended, as *mimetic* – they purport to present the form of things as they occur in the world. ... Against this mimetic tradition", Galison continues, "I want to juxtapose what I have called the 'logic tradition', which has used electronic counters coupled in electronic logic circuits." In the early 1980s, Galison points out, the "image" tradition and the "logic" tradition fused, "with the production of electronically generated, computer-synthesized images. It was just such an electronic 'photograph' that heralded the discovery of the *W* and *Z* particles in 1983 – the first time a single electronic detection of an event had ever been presented to the wider physics community as compelling evidence in and of itself."[45]

The emergence of digital graphics is of course only one aspect of the profound change in the course of which the computer has become an everyday element of scientific routine. When I say "computer" I mean, obviously, *the computer as part of the interactive multimedia global network*. Those patterns of mobility, immutability, compoundability, and demonstrability analyzed by Latour in his paper "Visualization and Cognition"[46] gain an entirely new meaning in the medium of the internet. Science as based on the book is replaced by science as based on the global network. The barriers separating different specialties seem today to become fluid once more. A new, transdisciplinary mode of science emerges. This change is not independent of the fact that, as Gibbons et al. put it in their book *The New Production of Knowledge*, "the density of communication among scientists through various forms of mobility has been greatly increased in recent decades", resulting in the "linking together of sites in a variety of ways – electronically, organisationally, socially, informally – through functioning networks of communication." Transdisciplinarity, write Gib-

[44] In the following paragraphs of the present draft I am taking over some formulations from my talk "Words, Pictures, and the Unity of Knowledge", cf. note 4 above.

[45] Chicago: University of Chicago Press, 1997, pp. 19 and 21.

[46] Bruno Latour, "Visualization and Cognition: Thinking with Eyes and Hands", *Knowledge and Society: Studies in the Sociology of Culture Past and Present*, vol. 6, Greenwich, CT: JAI Press. I have briefly described Latour's position in my "Pictorial Meaning and Mobile Communication".

bons et al., "has been facilitated through the availibility of ... enhanced means of communication". They stress that the computer is a tool that "generates a new language and images", that "the experimental process ... is increasingly complemented, if not in part replaced, by new computational models of simulation and dynamic imaging", and that this contributes to a "diffusion of ... techniques from one discipline to another". This new mode of science is characterized by problem solving "organized around a particular application", rather than by problem solving which is "carried out following the codes of practice relevant to a particular discipline".[47] When the importance of applied research in contrast with basic research is growing, the impression of coherence in everyday activities will be inevitably superimposed upon the image of fragmented scientific specialities. As Barbara Stafford puts it in her brilliant book *Good Looking: Essays on the Virtue of Images:*

> we need to forge an imaging field focused on transdisciplinary *problems*... But even [the] transdisciplinary initiative does not go far enough. I believe we must finally renounce the institutionalized notion that only the "pure" study of anything, including images ... is admirable. ... serious consideration should be given to the proposition that a great part of our most meaningful inquiry goes on precisely because it gives thought to practical ends. ... it is dynamic visualization that can transform an incomprehensible data file into more than a meaningless string of bits and pieces or an infinite series of unrelated fragments. Consequently, many astrophysicists, radiologists, meteorologists, and engineers have begun to decry the widening gap between the accumulation of raw numbers and their transformation into a visual format enabling practical analysis. Thunderstorm modeling and the animation of planetary magnetospheres represent only two small instances of how visualization of complex data – otherwise literally unimaginable – is now critical to the advancement of many fields of science.[48]

In philosophy there still dominates the mid-twentieth century position, according to which there is no such a thing as a world that is given – an in itself connected whole, describable by a coherent over-all theory.

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[47] Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, London: SAGE Publications, 1994, pp. 38, 6, 39, 45, 44, 3.

[48] Barbara Maria Stafford, *Good Looking: Essays on the Virtue of Images*, Cambridge, MA: MIT, 1996, pp. 10, 14 and 25.

By contrast, scientists today are by no means of a single mind when it comes to rejecting the possibility of a unified theory. Those who do reject such a possibility can be seen to be generalizing from their actual research experiences; but on the other hand, as Galison puts it in his introduction to the volume *The Disunity of Science*, they generalize certain social-political experiences, too. "[T]hese 'internal' scientific debates over fundamentality, reducibility, and so on, do not exist in a vacuum. They are profoundly embedded in a culture in which the quasi autonomy of different subcultures is valued as essential now in a way that it simply was not in the prewar years or even in the 1940's and 1950's."[49] Much research is conducted, even today, with the aim of developing a comprehensive theory. One can refer here to those efforts in physics Galison, too, lists;[50] or to the perspective offered in sociobiologist Edward Wilson's 1998 book bearing the subtitle *The Unity of Knowledge*. "Disciplinary boundaries within the natural sciences", writes Wilson, "are disappearing, to be replaced by shifting hybrid domains in which consilience is implicit. These domains reach across many levels of complexity, from chemical physics and physical chemistry to molecular genetics, chemical ecology, and ecological genetics. None of the new specialties is considered more than a focus of research."[51] The spirited talk given by Nobel laureate physicist Sheldon Glashow in 1989 at a symposium titled "The End of Science?" probably reflects the majority view of the scientific community. Philosophical scepticism will obviously not erode, said Glashow, belief in science as a "unified, universal, objective endeavour". "Does anyone really doubt", he asked, "the existence of the moons of Jupiter, which Galileo discovered centuries ago? Does anyone really doubt the modern theory of disease?"[52]

By way of conclusion, let me refer to Galison once more. He does not believe that physics divides into "self-contained and self-stabilizing" blocks. As he sees it, there is an "intercalation of diverse sets of practices (instrument making, experimenting, and theorizing) that accords physics

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[49] Peter Galison and David J. Stump (eds.), *The Disunity of Science: Boundaries, Contexts, and Power*, Stanford: Stanford University Press, 1996, p. 8.

[50] Cf. *ibid.*, pp. 5 ff.

[51] Edward O. Wilson, *Consilience: The Unity of Knowledge*, New York: Alfred A. Knopf, 1998, p. 11. I am quoting from the New York: Vintage Books, 1999 edition.

[52] The talk is referred to by John Horgan in his *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* (1996). Second edition with a new afterword, New York: Broadway Books, 1997, p. 62.

its sense of continuity as a whole, even while deep breaks occur in each subculture separately considered"; he believes that it is possible "to demonstrate the deep continuity of experimental practice through an analysis of the instruments of modern physics".[53] We seem to be back at Dewey's contention that there is no real separation between "pure science" and the laboratory. Indeed we are back at Copernicus' instruments. Instruments of visualization in the networked digital medium are major unifying forces in contemporary science.

[53] Galison, *Image and Logic*, p. 19.