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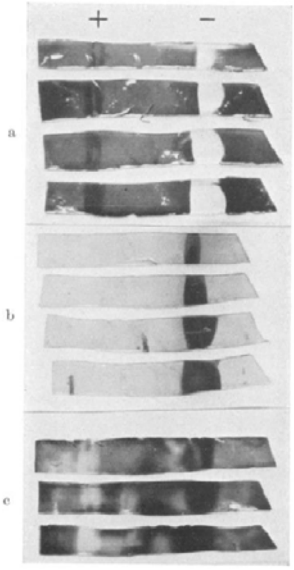
MODELS AS ERSATZ-OBJECTS

1. *Models/Things*

cyop&kaf guerriero#3

Somewhat famously, Martin Heidegger preferred to sample a rather wide range of items in the course of his many goes at being of *Being*, from the philosophically non-suspicious (well, seemingly unsuspicious) such as chalk, tables, hammers, shoes, stones, and lizards to the celebrated "jug" to the somewhat less orthodox things – van Gogh paintings, ancient temples, calculation machines, hydroelectric powerplants, car blinkers, trams, Fuhrer-transporting airplanes and more. Rarely, at any rate, were the items that paved Heidegger's various paths towards *Sein* particularly elementary, or indeed, "earthen" and "natural"; they were, in plain language, surprisingly artificial.



Nervous excitation as gelatine strips (1931)

What follows is not, however, a treatise on Heidegger's philosophy of things. Rather, it follows a little essay on models in science. More specifically, the following develops, in a necessarily somewhat sketchy fashion, a view on the historicity of scientific models; and what is more, an argument as to how to think about models – historically – rather than, that is, philosophically (as, arguably, even historians of science are prone to do). Still, this essay on models does take its cue from Heidegger's oeuvre; and to be precise, from a passage in *Being and Time* which includes the well-known observation that our most intimate "life-world" – or *Umwelt* – was in fact also the most distant and, regrettably, all too easily "skipped over" when it came to pondering the nature (or *Wesen*) of man, or life, or things[1]. More important even for present purposes, the passage also saw Heidegger pondering how, within this Umwelt, 'things also become accessible which need not be produced, that is, are ready-made always already':

> Hammer, pincers, nails as such refer to – they are made of – steel, iron, ore, rock, wood. With things-in-use, through using them, "Nature" is simultaneously uncovered - "Nature", that is, in the light of raw materials[2].

It is this notion of a nature mediated through things-in-use, or of an ontology of the ready-made, that interests me here. As I shall argue, it can be turned to good use in thinking about models historically: as a matter of cultural, as well as, material history.

Heidegger, of course, was hardly a philosopher of models – this was a business at home in another tradition of philosophy, and one that slowly got rolling in the 1940s and 1950s, associated with names such as Mary Hesse, Ernest Nagel, Max Black, Norbert Wiener and others; and one that is intimately associated with logic, semantics, abstraction and the formal - not things, concrete stuff and ready-made materials.

The former tradition has, not least, deeply shaped the ways students of science have approached questions of "models", including in the history of science, where – sign of the times – models (and related, metaphors, diagrams, simulations, analogies and the like) accrued an ever increasing prominence within the last two decades or so[3]. In fact, in the process, historians of science have done much to explode the apparently innocent category "model" into a myriad of different forms of modelling practices. Historians today more likely are pondering how models "mediate", are "used", or function socially – say, as "boundary objects" – rather than pondering how models "represent", or fall short of being true "theory". From dioramas to war games, from "blood drill" in army-training

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[1] M. Heidegger, *Sein und Zeit*, Niemeyer, Halle 1927, p.70.

[2] *Ibid*.

[3] See especially, M. Morgan, M. Morrison (eds.), *Models as Mediators: Perspectives on Natural and Social Science*, Cambridge University Press, Cambridge 1999; E. F. Keller, *Making Sense of Life: Explaining Biological Development with Models, Metaphors, and Machines*, Harvard University Press, Harvard 2002; S. de Chadarevian, N. Hopwood (eds.), *Models: The Third Dimension of Science*, Stanford University Press, Stanford 2004; M. N. Wise (ed.), *Growing Explanations*, Duke University Press, Durham 2004; A. Creager, E. Lunbeck, M. N. Wise (eds.), *Science without Laws: Model Systems, Cases, Exemplary Narratives*, Duke University Press, Durham 2007.

to wax-models in embryology, wind tunnels, TV-genic sticks-and-balls (re)presentations of molecules, analogue computers, flight trainers, engineers' scale models, boys' airplane kits, and industrial prototyping – all these things can be and, more significantly, *have been* considered as essential strategies of knowledge-production, -mediation, and -stabilization: matters of pedagogy, popular instruction, selling, persuasion, design, aids to the imagination, controlling phenomena, predicting and getting things done; nothing particularly logic, formal, or immaterial.

And yet, despite this greatly expanded panorama (and for that matter, despite a great many case-studies), the big historical picture is arguably still a different one. It circulates, implicitly at least, around the mid-twentieth century meta-narratives of cybernetics, the advent of scientific computing (simulations) and the incipient industrialization and commercialization of the life sciences – the latter reflected in the popularity of investigations into model-organisms such as *drosophila* or mice[4]. If the former – cybernetics – has come to enjoy the reputation of an ueber-science provoking an epistemic rupture of the first order (including, putting away with matter, energy and "representation"), the latter technologies, and their tremendous presence in all things scientific today, no doubt is reflected in the surge of historical interest in "models", as well as, in our historical sensibilities concerning periodizations and the nature of modelling practices.

Like most meta-narratives, this one isn't, of course, without plausibilities – even though well worth questioning in its assumptions. For instance, it is a big picture based mostly on developments within academic research, by and large ignoring the realms of applied science, engineering and industry. More to the point here, in fact we still lack comprehensive, and historicizing, accounts of rise of scientific modelling practices in the course of the twentieth century – and of the parallel rise of model-centric epistemologies and psychologies of science as well[5]. Needless to say, the following considerations are concerned with a set of rather more modest questions (though they do speak to these

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[4] On model-experiments, see R. Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* University of Chicago Press, Chicago 1994; K. A. Rader, *Making Mice: Standardizing Animals for American Biomedical Research, 1900-1955* Princeton University Press, Princeton 2004; on computing, G. Gramelsberger (ed.), *From Science to Computational Sciences. Studies in the History of Computing and its Influence of Todays Sciences* (forthcoming, 2010).

[5] See however, J. Cohen-Cole, *Thinking About Thinking in Cold War America* (PhD. thesis, University of Princeton, 2003).

larger issues as well). My main aim is to make plausible a notion of models as an aspect of Nature “ready-made”, or as what I call *Ersatz-objects*: a matter of uncovering nature through substitutions of one thing (known) for another (unknown).

The aim, in other words, is to put models back into the material fabric of the world: their historical, material surroundings, and hence, much larger histories of materials – histories of producing, using, and knowing things-in-use. Quite generally, the following is about complicating common assumptions made about the objects of “natural science”. And in particular, it is about thinking differently, and more inclusively, about models. Models and modelling practices, on this view, will appear as nothing peculiar or particularly exotic (certainly, they will appear as no more peculiar than computer simulations, for instance, or model-organisms). In putting centre-stage their materiality, they will appear instead as profoundly historical entities, deeply enmeshed and interwoven with the ways natural knowledge was mediated through things-in-use – at large[6].

Considered in a little more detail here is the case of chemically manufactured things; and as such, the case of models of the biological cell in the interwar period. Or more properly, considered is the case models of the cellular *surface*: a rather elusive, if fundamentally important, entity. Its intricate details and distant, miniscule dimensions weren’t easily fathomed in the period between the wars, which was a period – important for present purposes – otherwise characterized by a tremendous technological optimism (and anxieties) as regards the malleability of the world – malleable through science, that was; and in particular, through chemical science. It is the incipient era of plastics, semi-synthetics, and the chemical industries, then, that will interest us most, and of a plethora of new and increasingly colourful things: the era of DuPont and I. G. Farben, and of dreams of national autarky, of viscose and celluloid, Bakelite, insecticides, margarine, and artificial silk; in short, of a chemically engineered, man-made world[7]. Everywhere one looked, science journalist John Pfeiffer wrote in 1939, one saw the «moldable rivals

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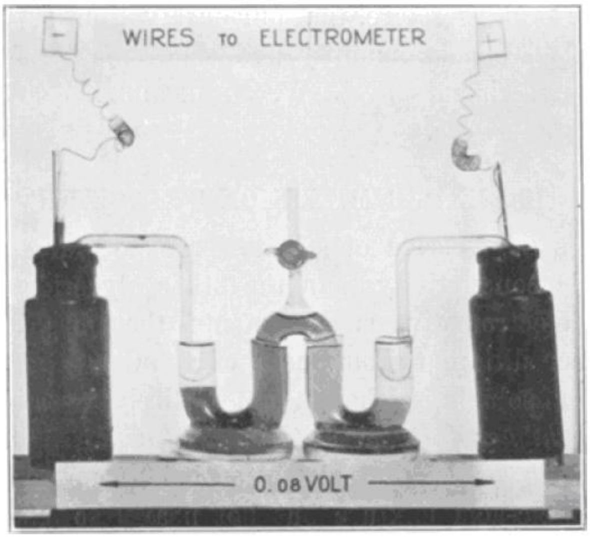
[6] For an extended argument along these lines, see M. Stadler, *Assembling Life. Models, the cell, and the reformations of biological science, 1920 – 1960* (PhD thesis, Imperial College London, 2010).

[7] See, for instance, J. Meikle, *American plastic: a cultural history*, Rutgers University Press, New Brunswick 1995; S. Mossman (ed.), *Early plastics : perspectives, 1850-1950*, Leicester University Press, Washington 1997.

of metal, lumber, china, and such materials that go into the making of objects for your home and office, [they] are all around you in various forms»[8].

As we shall see, brought together in the materiality of models, it was this moldable, artificial world of useful products and processes that mediated the seemingly "natural knowledge" of the biological cell, in ways not so much unlike Heidegger's proposition above. And not, in fact, altogether surprisingly so: because they were so pervasive, and so widely in use, few things and processes were as intimately known as well.

2. *Cellular models, interwar-style*



The cell as olive-oil battery (1930)

To be sure, the story of cellular knowledge as mediated through the materiality of models, as historians Andrew Mendelsohn and, more recently, Thomas Brandstetter have shown, reaches back long into the nineteenth century, indeed beyond. The cell always already coalesced around "exemplary materials" – everyday and "uncontested" things such as cork, cartilage, or eggs[9]. But the story comes into its own only in the twentieth century. Then, on scales unprecedented, things-in-use, in virtue of their being known – subject to analysis, test, refinement, processing and control – turned "exemplary" in the sense of an ontology of the ready-made: generating and informing theories of biological membranes on the one hand, providing the raw material for modelling practices on the other. Or this, is the gist of the argument to follow.

It was not least then, in the period after WWI, that so-called "model experiments" turned into something of a routine, normal practice in the life sciences – a story, it's

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[8] J. Pfeiffer, *Plastics - Modern Marvel of Science*, «Mechanix Illustrated», June 1939, p. 54.

[9] J. A. Mendelsohn, *Lives of the Cell*, in «Journal of the History of Biology» 36, 2003, pp. 1-37; T. Brandstetter, *Leben im Modus des Als-Ob. Spielräume eines alternativen Mechanismus um 1900*, in A. Avanessian, W. Menninghaus, J. Völker (eds.), *Vita Aesthetica. Szenarien ästhetischer Lebendigkeit*, Diaphanes, Zürich 2009, pp. 237-249.

worth emphasizing here, which, just like its historical circumstances, is all too easily obscured by the contemporary (and even more so, subsequent) excitement that began to surround the discourse of the "molecular" (as well as, newly emergent disciplines such as, notably, biochemistry). Influential voices such as Cambridge icon of biochemistry Frederick Hopkins then rejoiced in deriding the «less specific properties of colloid systems, phase surfaces, membranes and the like»[10]; for historians too, the period in these respects went down as one of "Disciplinary Program[s] That Failed" or even, as a "dark age of biocolloidity", thus implicitly acknowledging at least, the significance at the time of surfaces, colloidal systems "and the like"[11]. The point here indeed is to see beyond novelty, and the partisanship of fairly academic debates, and to recover something of the more subterranean layers of scientific knowing – the ontology of the ready-made – that informed and sustained the production of cellular knowledge.

And few things loomed as large as "surfaces" in the ways that the ready-made was "uncovered" at the time. The interwar period was a world of more or less artificial structures (and processes) "known" not least in terms surfaces, and surface processes, thanks to advances made, notably, in the chemical industries and sciences such as physical chemistry, surface chemistry, or colloid science: a world of new, and newly understood, materials and things – things refined, processed and improved, things increasingly synthetic, and increasingly colourful.

In short, if not everything turned wholly synthetic, it was not only that useful, novel and man-made products swamped interwar economies; they were well-charted ones at that. The "outstanding characteristic" of the times, as one entrepreneurial chemist declared in the 1926, was the "recognition" of the less simple forms of matter as a legitimate object of scientific inquiry:

> the industries based on vegetable and animal products and minerals used as such – textiles, paper making, rope and twine, leather, building construction ... paints and varnishes, glass,

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[10] F. Hopkins, *The Mystery of Life*, in «The Times», 7 September 1933, p. 6.

[11] M. Florkin, *A history of biochemistry*, American Elsevier Publishing Co., New York 1972; J. Servos, *A Disciplinary Program That Failed: Wilder D. Bancroft and the Journal of Physical Chemistry, 1896-1933*, in «Isis», 73, 1982, pp. 207-232; but see, N. Morgan, *The strategy of biological research programmes: reassessing the 'Dark Age' of biochemistry, 1910-1930*, in «Annals of Science», 47, 1990, pp. 139-150; A. Ede, *The Rise and Decline of Colloid Science in North America, 1900-1935: The Neglected Dimension*, Ashgate, Burlington 2007.

> porcelain and earthenware, india rubber, military explosives, starch gum, gelatine and casein [...] coal and foodstuffs[12].

It was a new branch of the physical sciences – colloid science – that especially resonated with these not very simple but “complex” phenomena: a veritable science of complexity avant-la-lettre, in fact; a true physics and chemistry of “everyday life”, in the words of one such colloid scientist[13].

And the point here is little more than to indicate how the alliance of the cell, models and materiality at issue was as deeply grounded in this everyday, distributed knowledge of things-in-use. Once unearthed and (re)articulated, it was, epistemologically speaking, immensely productive, as we shall see. But it was a matter of intentional strategy only to limited degrees – making models was as much about “uncovering” them, as when students of cellular life deliberately diverted the ready-made things at hand for modeling-purposes, say, “market soaps” and their “foaming properties” to replace what would have remained elusive otherwise: the dynamic behaviours of the cell surface[14]. These diverted materials belonged, above all, to the sphere of fabricated things: a piece of cellophane foil for instance – concrete part of the world[15].

The connecting thread, as far as cellular knowledge was concerned, and which traversed these various landscapes and spaces of things, was the “problem” of cellular permeability – its “inner causes” in particular, in the words of one membrane-scientist[16]. The mysterious why and how of substances moving across living surfaces – against all thermodynamic odds – then unquestionably belonged to the fundamental criteria of life; not to mention, the immense practical importance of the subject matter, ranging from plant nutrition to the propagation of the nerve impulse. Few problems, in fact, drew comparable attention on part of students of the living cell; and students of the cell then turned legion, operating in and even more so, beyond academic laboratories: plant physiologists, general physiologists, biophysicists, colloid scientists, neurologists, toxicologists and public health scientists, students of nutrition, food chemists, medical

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[12] C. F. Cross, *Chemistry Of Cellulose. Complex Colloids. Avenues Of Research*, «The Times», 9 March 1926, p. VIII.

[13] W. Bancroft, *Applied Colloid Chemistry: General Theory*, McGraw-Hill, New York 1921, p. 2.

[14] M. Fischer, M. Hooker, *On the Physical Chemistry of Emulsions and Its Bearing upon Physiological and Pathological Problems*, in «Science», 31 March 1916, pp. 468-472.

[15] J. W. McBain, S. Kistler, *Membranes for ultrafiltration, of graduated fineness down to molecular sieves*, «Journal of General Physiology», 12, 1928, pp. 87-200.

[16] L. Michaelis, *Die Permeabilität von Membranen*, in «Naturwissenschaften», 14, 1926, p. 34.

physicists, chemical physicists, industrial scientists, investigators of textiles, leathers, and fibres.

Certainly enough, the "living" cell here never was without inherent ambiguities, always tilted towards application and technical ends. And indeed, the two major, competing conceptions concerning the cellular surface had it written in their names, i.e. the extent to which these were "oriented towards systems of the macroscopic world". Interwar conceptions of the cell's surface thus formed around two kinds of things: theories of "pore", "sieve" and "filter" – like structures on the one hand, that of "oily", "fatty" (lipoid), and "non-aqueous" surfaces on the other[17].

And let us turn now to their material, and thingy, basis: the backdrop to this hugely influential vision(s) of the cell, which was a veritable culture of "mimetic" modelling[18], a culture itself integral to an economy of "substitution" and cultural climate fascinated with the analogical, and the conflation of nature and artifice[19]. Or, one branch at least of this mimetic culture we can briefly sketch in the remainders of this essay: the one concerned with "oily" surfaces. It was, like its contenders, a conception firmly anchored in the world: here as there, everything was a question of the right kind of *Ersatz.* For, to be sure, the cell, its putative composition and functions, were widely perceived as beyond vision and intervention at the time. Knowledge of the cellular life, it was widely believed, could never be "direct". «Because the dimensions are so small», as one biologist explained the obstacles one faced in around 1930, «the possibility of elucidating the structure of the plasma membrane, for the time being, doesn't exist; it remains the indirect method of investigation by way of comparison with membranes of known structure»[20].

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[17] For instance, E. Gellhorn, *Das Permeabilitätsproblem, seine physiolog. u. allgemeinpatholog. Bedeutung* Springer, Berlin 1929; R. Höber, *Permeability*, in «Annual Review of Biochemistry», 1, 1932, pp. 1-20; W. Wilbrandt, *Die Permeabilität der Zelle*, in «Ergebnisse der Physiologie», 40, 1938, pp. 204-291.

[18] The notion of 'mimetic' modelling is borrowed from P. Galison, A. Assmus, *Artificial Clouds, Real Particles*, in D. Gooding, T. Pinch, S. Shapin (eds.), *The uses of experiment: Studies in the natural sciences*, Cambridge University Press, Cambridge 1989, pp. 225-274.

[19] For instance, M. Orvell, *The Real Thing: imitation and authenticity in American culture*, University of North Carolina Press, Chapel Hill 1989; E. Leslie, *Synthetic Worlds: Nature, Art and the Chemical Industry*, The University of Chicago Press, Chicago 2005; generally, see B. Bensaude-Vincent and W. R. Newman (eds.), *The Artificial and the Natural. An Evolving Polarity*, MIT Press, Cambridge 2007.

[20] R. Mond, *Einige Untersuchungen über Struktur und Funktion der Zellgrenzschichten*, «Protoplasma», 9, 1930, pp. 318-330.

And known structures, there were plenty; indeed, quite complex ones at that: in their hey-day, the 1920s and early 1930s, such complex (because colloidal) structures – emulsions, jellies, sols, films, and filaments, and the phenomena of swelling, adsorption, mixing, and stability – came together under the rubric and umbrella of the colloidal state of matter[21]. Technically a type of mixture consisting of two phases (a dispersed phase, and a dispersion medium), colloidal systems were anything that was not "simple". The result was a true "surface world", as a 1926 *Introduction to Surface Chemistry* diagnosed; and one that was of the «highest importance for the understanding of great regions of natural phenomena», not least, the great many phenomena of life which were «intimately concerned with the actions occurring at surfaces»[22].

From a theoretical point of view, the excitement surrounding this surface world owed much to the recent investigations into just that: surfaces. Technically, it owed to recent developments in laboratory technique, notably the ultra-microscope, ultra-filters, and ultra-centrifuges – all of which made their appearance during the early decades of the century, and being "ultra", resolved things into hitherto neglected dimensions. And it simply owed to the surge of investigations into everyday, and thus non-simple, and thus presumably colloidal objects.

Its worldly character is of prime importance here: it was this surfacial world of material complexity which emerged as a focal point of conceptual and material exchange, provoking and enabling the conflation of surfaces, materials, and Ersatz-objects. The cell, formerly taking shape as static tissue slices on microscope slides, now gradually gave way to a dynamic, teeming aggregate of phase-reversals, surface tensions, gel formations, and viscosity changes: this was stuff of the biological cell according to interwar textbooks; but more fundamentally, it was here – on the level of materiality – that "models" blurred with knowing through the ready-made at large; that concepts migrated, and experimental technologies were diverted to novel ends.

By the 1930s, a great many model-making students of the cell were engulfed in this very surface world: they ranged from prestigious institutions, such as W. J. V. Osterhout – successor of the famous Jacques Loeb at the Rockefeller Institute – to Cambridge, where students were exposed to the cell as the swelling of cellulose, gels, films, emulsions, or

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[21] See especially, A. Ede, *The Rise and Decline of Colloid Science in North America, 1900-1935*, cit.

[22] E. Rideal, *An introduction to surface chemistry*, The University Press, Cambridge 1926, *Preface*.

soaps – materials “studied intensively” (if usually not, as it was duly pointed out, through a “biochemical call”[23]); and significantly, they included such lesser mortals as Henry Proctor, a famed pioneer, in fact, of a science of leather manufacture and tanning; figures such as British botanist Walter Stiles, an authority as well in matters of food preservation and the author of a pioneering survey on “permeability”[24]; or again, they included the two figures who will feature somewhat more prominently below: George Clowes, research director at the Eli Lilly Company, and Martin Fischer, Professor of Physiology in Cincinnati, and for his part an expert on soaps and oedema. They all were engaged, among many other things (evidently), in what was commonly referred to as model-experiments, artificial models, imitations, or Modellversuche. The real agents in this story were the materials, however – much less so, individuals and particular institutions, or their intellectual programmes and philosophical agendas.

3. *Reversals*

Let us follow, then, the materials: among other things, cellular model-experiments could be based such inconspicuous – but well-elucidated – items as cellophane foil, one of those interwar, material novelties; even more popular, they could be based on collodion – the stuff of photographic plates and a whole spectrum of useful products that ranged from viscose to paints and lacquers – and other such “membranogenic” substances, which then were becoming available commercially, notably, for the purposes of industrial filtration and laboratory use. Or, it could be based on complex layerings of casein, gelatine, agar, iron precipitations and other such familiar and “controllable substances”, as was the preferred strategy of Rudolf Höber, the noted author of *The Physical Chemistry of the Cell*, and the influential, so-called “Finnish school” of plant physiology as well[25]. Or again, they could be based, as in the example I want to develop a little further now, on emulsions – made up of soaps – in order to “imitate” bio-electric phenomena and, especially noteworthy, certain “reversal” effects as well[26].

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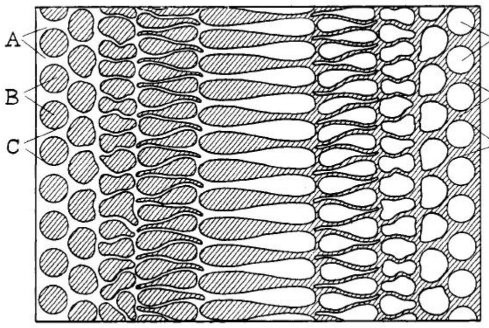
[23] L. Blinks, *Winthrop John Vanleuven Osterhout*, in «Biographical Memoirs of the National Academy of Sciences», 44, 1974, pp. 217-254; cited in «Surface Phenomena VI» (lecture MS), F. Roughton papers, Box 34.40u, American Philosophical Library, Philadelphia.

[24] On details, see Stadler, *Assembling Life*, cit., *Chapter 1*.

[25] *Ibid*.

[26] See, notably, R. Beutner, *Physical chemistry of living tissues and life processes : as studied by artificial imitation of their single phases*, Williams & Wilkins Company, Baltimore 1933; and below.

Concocting emulsions was, for one, the method of choice of Clowes and Fischer above, both of whom hand their hands in the creation of the so-called "emulsion reversal theory" of the cellular surface – easily one of the most influential accounts of cellular nature in the early decades of the last century. If so, it was not least because the emulsive nature of the cellular surface well-grounded in the material world indeed: a theory not based on observation, not even mere experimental intervention, but on concrete manufacture. To illustrate such model-mediated manufacture of knowledge, then, let us briefly consider the case of the reversal theory: a theory that posited a cellular surface which underwent "changes" very much like a system of oil-drops dispersed in water – "like in cream", as Clowes said – would "change", under certain conditions, into dispersions of water in oil, "like butter"[27].



The cellular surface as emulsion reversal (after Clowes, 1916)

The reversal theory was a product of this world, scaffolded – and contested – by a great many Ersatz-objects: from motor oils – high-grade and their physical characteristics – specific gravity, boiling range, molecular weight – well established – to deep-frozen gelatine and on to, of course, emulsions – notably of soaps. Again, there is nothing particularly surprising here. Few chemical systems were as well-charted as the latter, and not least those on which "commercial soap manufacture" depended, as the versatile soap-scientist James McBain noted, ever aware of the wider ramifications of his subject matter[28]. The literature on "technical emulsions" was correspondingly huge; and it offered a rich, and material, pool of practical knowledge, including such uncannily life-like phenomena as the "salting out" of soaps – ion-induced precipitation phenomena; the stability and dynamics of soap film formation; even, «the study of the[ir] life-history [...] or formation in its genesis and subsequent transformations»[29].

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[27] G. Clowes, *Protoplasmic Equilibrium*; «The Journal of Physical Chemistry», 20, 1916, p. 421.

[28] J. W. McBain, F. Kellogg, *The Salting Out of Gelatin Into Two Liquid Layers with Sodium Chloride and other Salts*, in «Journal of General Physiology», 12, 1928, p. 3.

[29] For instance, A. Lawrence, *Soap Films: a Study of Molecular Individuality*, G. Bell, London 1929; J. W. McBain, *Soaps and the Theory of Colloids*, «Nature», 23 May 1925, pp. 805-807.

Indeed, the reversal theory itself – subject to some heated priority disputes – was a matter of multiple origins, surfacing, in the midst of WWI, notably as the work of said Fischer and Clowes. And both Fischer and Clowes, in creating their “theory”, were in intimate touch with the things-in-use, immersed in a world of soaps, oils and technical emulsions. Fischer, we already know, was a physiologist but also an expert of soaps and such «technical problems» as were «embraced in the making of butter» (masterfully demonstrated in his 1921 monograph on *Soaps and proteins; their colloid chemistry in theory and practice*)[30]. Clowes, meanwhile, better known for his later involvement in the standardization of insulin, was the director of research at the Eli Lilly Company from 1920, and he had served, during WWI, at the US Chemical Warfare Service studying the action of nerve gases and the – hopefully “protective” – action of certain ionic species against them. Even before, then working at the State Institute for the Study of Malignant Disease in Buffalo, Clowes, a trained chemist, had developed an interest in the effects of ions on tumors[31].

Clowes’ route to cellular surfaces was a different one from that taken by Fischer, whose own interest was prompted by oedema. In their struggles with the elusive microworld of the living however, they arrived at remarkably similar things – Ersatz-objects: Fischer’s turn to soaps thus was the result originally of a desire «to understand the laws of water adsorption as observed in living matter», and hence, the effects of salts (ions) on tissues: by 1920, he had found “surer ground” in soaps, in virtue of their ‘more controllable number of purely chemical variables. The «laws governing the “solution’’ and “hydration’’ of soaps», as Fischer’s researches showed, «are the analogs of the laws which govern the adsorption of water by cells»[32]. Clowes, too, was deeply impressed by the behaviour of such systems, which were easily made to undergo rapid transitions between various conditions: “reversals”. And such behaviour deeply resembled that of biological systems, as Clowes had determined for himself by 1914 at the latest, then busy injecting salt-solutions into mice and blood plasma in order to “duplicate” the

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[30] M. Fischer, M. Hooker, *On the Physical Chemistry of Emulsions and Its Bearing upon Physiological and Pathological Problems*, cit., p. 468.

[31] On Clowes, see J. McK. Cattell, D. R. Brimhall (eds.), *American men of science*, Science Press, Garrison 1921.

[32] M. Fischer, M. Hooker, G. McLaughlin, *Soaps and proteins: their colloid chemistry in theory and practice*, John Wiley and Sons, New York 1921, *Preface*, p. 205.

"disturbing" effect of negative ions (and the "protective" action of positive ones); they could be found to affect, in "analogous" fashion, the stability of oil-water emulsions. In all these cases, as Clowes noted, stability depended on the presence of emulsifying agents, or soaps, which acted – as it was well-known enough – notably by promoting the formation of membranes[33].

In short, the theory of the cellular membrane changes as "reversal" effects was articulated materially amidst, and by means of, a range of "controllable" substances. It was Ersatz-objects of this kind which made imaginable a basis for those strangely "analogous" effects and thus, the action of ions, toxins, or nutrients on biological systems – far less controllable systems, and indeed, inaccessible otherwise. And indeed it is here, I would argue, as epiphenomena of the synthetic, everyday and ready-made, that the historical interest of "model-experiments" resides: in showing up the historical and material entanglements of model-based forms of knowing. We should be wary in turn of portrayals of such practices within biology as particularly "metaphoric", isolated curiosities, or as simply misguided and brutally mechanistic[34]; they were neither. They were as concrete, and nearly as omnipresent, as the material things which informed them: it was in virtue of being known, controllable, and ready-to-hand, that the materiality of the ready-made served to illuminate the unknown as well.

4. *Conclusions: ontologies of the ready-made*

In the interwar period, the idea – and practice – of modelling by way of Ersatz was, quite evidently, palpable. The likes of Fischer and Clowes did little more than appropriate – by mixing, shaking, assembling – the materializations of knowledge around them. Their business was "imitation experiments", the logic of which was made explicit at the time in treatises such as Ludwig Rhumbler's *Methodology of the Imitation of Life Processes through Physical Constellations* (1921): choosing the suitable ingredients, composing an artificial system, testing its physical characteristics, finally, comparison with the biological

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[33] See, especially, G. Clowes, *Die Wirkung der Elektrolyte bei der Bildung und Umkehrung von Oel-Wasser-Systemen, mit einigen biologischen Anwendungen*, «Kolloid Zeitschrift», 15, 1914, pp. 123-126; G. Clowes, *Antagonistic Electrolyte Effects in Physical and Biological Systems*, «Science», 26 May 1916, pp. 750-757.

[34] On such renderings, see P. Agutter, P. Malone, D. Wheatley, *Diffusion Theory in Biology: A Relic of Mechanistic Materialism*, in «Journal of the History of Biology», 33, 2000, pp. 71-111; E. Fox-Keller, *Refiguring Life: Metaphors of Twentieth-Century Biology*, Columbia University Press, New York 1995; M. Lindner, *Der Stoff, aus dem das Leben ist*, in «NTM», 8, 2000, pp. 11-21.

reference system. By maximizing the “number of parallels” between imitation and original, a “suitably composed system of liquids”, could serve as “indirect evidence” that physical processes “performed”, as Rhumbler wrote, in identical fashion, in the protoplasmic substance of the cell[35].

It would be going to far to follow up here on all the various incarnations of such compositional, mimetic experimentation, or its perceived limitations and critics (of which there was no shortage either, to be sure). Neither is this the place to expand on its eventual displacement by the “molecular” and “cell biology” proper which, aided by novel techniques such as electron microscopy, created if not an entirely new, still a very different, cell – and one less obviously indebted to things of the macrocosm. Suffice it to say that the exploding sciences of the cell in the interwar period, scattered as they were, were traversed by the mimetic spirit, as much as they tended to emphasize the physical, the quantitative and not least, the practical: expressions of the material relations of cellular knowing. Certainly, the “engineering ideal” in interwar biology was more rampant than intellectual history would seem to suggest[36]. Major monographs, laboratory manuals, text-books and the popular literature, they all bore witness to the “system of surfaces” that was the cell, and they all were inflected by the materiality surrounding them. The «true secrets of this world», after all, then weren’t to be «dug up from the dusted libraries and they [weren’t] to be found in the dark chambers of the laboratories»[37].

Indeed, they weren’t. At least the secrets of the biological cell, as we have seen, were very much of this world. And let’s keep in mind that the case at hand is, indeed, only a special case. Much the same argument could be made, for instance, about the innumerable electrical things which began to populate interwar life-worlds[38]; or – familiar at least in principle to anyone versed in the history of molecular biology – about the intimate entanglements between the contemporary, nascent elucidation of the

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[35] L. Rhumbler, *Methodik der Nachahmung von Lebensvorgaengen durch physikalische Konstellationen* Urban und Schwarzenberg, Berlin und Wien 1921, pp. 221-222.

[36] P. J. Pauly, *Controlling Life: Jacques Loeb and the Engineering Ideal in Biology*, Oxford University Press, New York 1990.

[37] F. Kahn, *Das Leben des Menschen*, (Band I), Franckh, Stuttgart 1926, pp. 22-23.

[38] M. Stadler, *Assembling Life*, cit., *Chapter 3*.

molecular and the burgeoning interwar textile, fiber and rubber industries[39]. Indeed, within recent years a great many studies in the history of science have dealt, more or less explicitly, with the material mediations of knowledge that is at stake in following: Ursula Klein's work on eighteenth century chemistry is a case in point[40]; the work by Simon Schaffer and others on nineteenth century telegraph networks and physics another[41]; and much the same is true for the work by historians of technology who have uncovered the basis of information theory within interwar telephone and power engineering, or computers and state bureaucracies[42]. In all these cases, the substrate of *natural* knowledge was formed, quite literally so, by the materiality of useful and artificial things.

Here, taking seriously the notion that it was in virtue of their materiality – as Ersatz-objects – that (certain) models work, not least pointed to something of an escape route from the still dominant representational paradigm in our theoretizations of "models", the contaminant focus on the discursive (metaphors, analogies and so on) and contemporary technologies such as model-organisms and computer simulations. More significantly, it allowed re-embedding the practices of model-experimentation within the broader currents in the history of twentieth century science, technology and culture: it was the synthetic, material world of the interwar period that made coalesce a culture of scientific modelling that was profoundly informed by, and made use of, the manifold, moldable, and most of all, substitutable, things of the day. Indeed these were practices that participated, and made sense, in a cultural climate broadly tuned towards the mimetic: a much wider intellectual, aesthetic, and not least, economic, drive towards "substitution", and as such, the blurring of boundaries between the natural and the artificial, the micro and macro. The mediation at stake was, to be sure, a multi-layered process, and the reality-effects of cellular Ersatz operated on many levels. Clearly

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[39] D. Berol, *Living Materials and the Structural Ideal: The Development of the Protein. Crystallography Community in the 20th Century* (PhD. thesis, University of Princeton, 2000).

[40] U. Klein, W. Lefèvre, *Materials in Eighteenth-Century Science: A Material Ontology*, MIT Press, Cambridge 2007.

[41] See, especially, S. Schaffer, *Late Victorian Metrology and its Instrumentation: a Manufactory of Ohms*, in R. Bud, S. Cozzens (eds.), *Invisible Connections. Instruments, Institutions and Science*, SPIE Optical Engineering Press, Bellingham 1992, pp. 57-82; B. Hunt, *The Ohm Is Where the Art Is: British Telegraph Engineers and the Development of Electrical Standards*, in «Osiris», 9, 1994, pp. 48-63.

[42] F. Hagemeyer, *Die Entstehung von Informationskonzepten in der Nachrichtentechnik* (PhD. thesis, Free University Berlin, 1979); D. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*, The Johns Hopkins University Press, Baltimore 2002; J. Agar, *The Government Machine: A Revolutionary History of the Computer*, MIT Press, Cambridge 2003.

however, the objects of such “natural knowledge” – enmeshed in an ontology of the ready-made – turned out to be less obviously natural than what a narrow focus on the biological laboratories, or dusted libraries, might seem to suggest. In these interwar worlds, models-as-substitutions indeed were uncovered, as it were, *naturally* – part and parcels of a Nature that was uncovered “in the light” of things-in-use, as Heidgger, as one of its perceptive inhabitants, saw clearly enough.

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