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Nicolò Ceccarelli

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Nicolò Ceccarelli

THINGS ARE (NOT) ALWAYS WHAT THEY SEEM.
Animating scientific visualization: the case of anatomy

Is the invisible visible?
H. Dam, interviewing W.Röntgen in 1896,
soon after the discovery of X-Rays.

To the sharpest naked eye, all this would be invisible
voiceover, Hemo the magnificent

Man is the measure of all things
Protagoras

ABSTRACT
The voyage that humankind began in the 16th Century towards scientific knowledge is most fascinating. Interestingly, the quest for knowledge to Modernity followed with equal intensity two apparently opposite directions. As the discovery of the New World was opening the way to a season of explorations of unknown far away places, another journey started taking place towards a different uncharted territory: the inside of the human body.
The ways devised to record and disseminate the findings of such parallel explorations still stand among the most sophis-

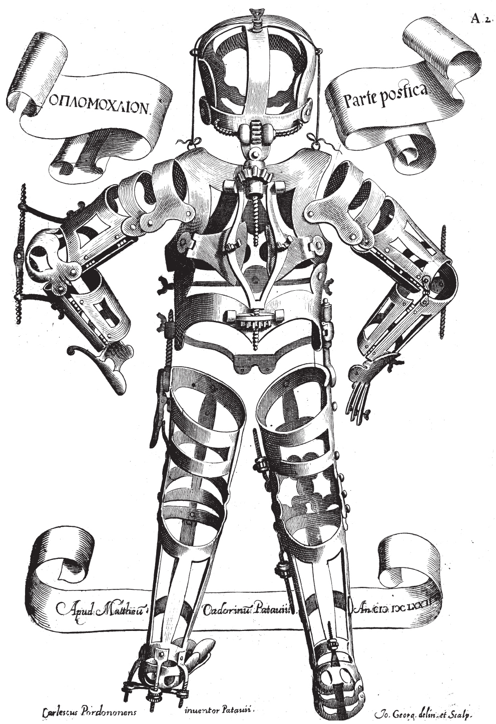


Fig. 1.

Girolamo Fabrizio Acquapendente (1533-1619), Opera Chirurgica.

ticated and interesting instances of technical and scientific visualization.

Following an overview of some of the key steps in this history, this article focuses on the evolutionary path to anatomical and medical visualization. From the early great anatomical atlases of the past – Vesalius, Albinus, Hunter – to their contemporary counterparts. From Dr. Fritz Kahn’s medical popularization books, the walk-in large exhibits of the kind Will Burtin designed for Upjohn in the 1960’s, to the medical illustrated atlases by Dr. Frank H. Netter. We will then move to examine other approaches to the dynamic representation of the inner workings of the body, from medieval paper flap models to contemporary Virtual Reality interactive 3D anatomical models, through what UK animators Halas & Batchelor described in 1949 as animation’s “penetration” principle: the capacity to present *the internal workings of an organism*. We will symbolically close our journey by discussing the cornerstone 1968 scientific documentary *Powers of Ten* by the American designers Ray and Charles Eames.

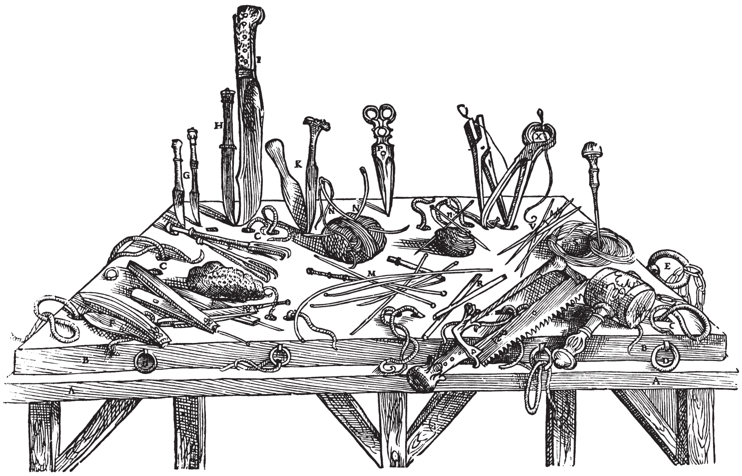


Fig. 2.

The ‘scamnus anatomicus’ portraied in Vesalius’ 1543 *Humani Corporis Fabrica* is a key representation of the new path to science and knowledge.

Knowledge navigators

In its rugged, gruesome look to the eye of the non specialist, the dissection table presented by Andreas Vesalius in his *Humani Corporis Fabrica* is a powerful and multi-layered metaphor. Crammed with ripsaws, scalpels, cleavers, threads and needles, Vesalius’ *scamnus anatomicus,* epitomes one of the starting places of the journey that from ‘500 humankind undertook towards the exploration of the universe.

A true journey was in fact what the explorers of the new needed to depart from blind faith, tradition and conventional thought, in their quest for a new kind of knowledge built upon direct inquiry and experimentation. Rigorous, rational exploration and the observation and interpretation of facts became the foundations over which, through the scientific method, humankind took its way to the modern world. It is not by coincidence if 1543 is the same year in which both Vesalius’ *Fabrica* and Copernicus’ *De Revolutionibus Orbium Coelestium* where published. The *grand voyage* undertaken to fill the gaps of human knowledge, from the immensely vast to the immensely small, was to be a multi-dimensional one.

Humani Corporis Fabrica was a large in-folio volume, structured in seven books covering the body's main systems. Although not the first illustrated anatomical book, the atlas presented an unusual visual richness and accuracy. Thanks to the clarity of Stephan Calcar's woodcuts, its graphic layout became a template: a standard of excellence that was to last for Centuries. Rightly considered as a true cornerstone of the new science[1], the book "greatly advanced the capacity of printed images to provide identical information that could be reviewed simultaneously anywhere, a founding tenet of modern scientific method"[2].

Vesalius' volume was not only a vehicle for disseminating knowledge: it was itself an embodiment of a new world based on inquiry and on the sharing of knowledge[3]. *Fabrica*'s allegorical frontispiece carried a message: a common feature in books at that time. Andreas Vesalius, the author-surgeon himself, was depicted in the process of performing a dissection in front of a vast audience. Staged in a specific architectural setting, a vast Renaissance hall, possibly an anatomical theatre, the scene confirms the volume's didactic purpose. At the side of the dissected corpse, Vesalius is lecturing, presenting facts on the grounds of scientific evidence. As knowledge is now acquired through direct investigation, the body he is examining has become the anatomical book itself.
A powerful symbol for a new era.

As the publication of the *Fabrica* had a major impact in the development of the study of anatomy discipline, explorations by scholars throughout Europe followed soon, starting to fill the gaps still exhisting in the understanding of the human body's workings. This of course required an increased quality in illustration, that had been meanwhile made possible by improvements in printing technology. The engraving on copper plates,

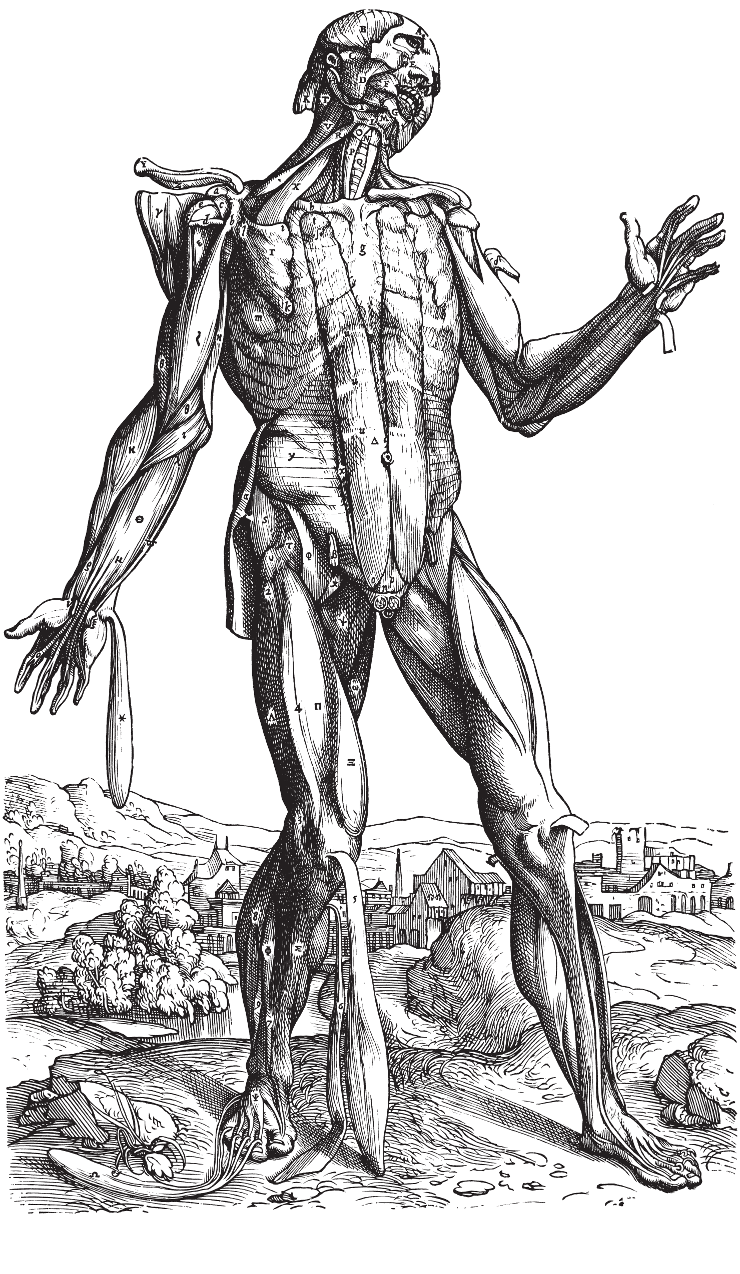


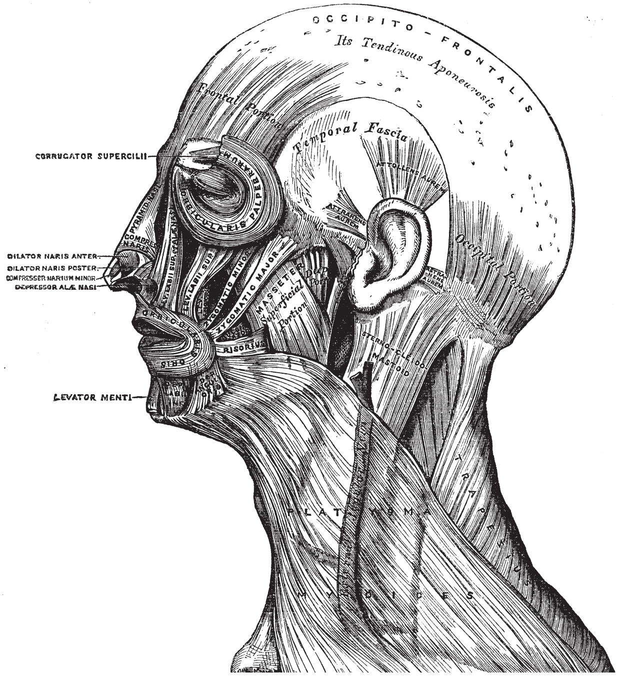
Fig. 3.

Vesalius’ Fifth Plate of the Muscles.

one of the emerging techniques, allowed to extend the *chiaroscuro* tonal range, introducing convincing shading effects. This coud be exploited to render volume, mass, organs and soft tissues with increasing detail and realism. Through the 17th and 18th centuries, a number of seminal studies based on excellent iconographic apparatus made their appearance, among which Albinus' *Tabulae sceleti et musculorum corporis humani* (Leiden, 1747) and William Hunter's *Anatomy of the Hunan Gravid Uterus Exhibited in Figures* (Birmingham, 1774).

The need of visual standards enabling the recording of the scientific experience and making it reproducible – one of the tenets of the New Science itself – is among the driving elements of the development of scientific illustration as a proper discipline. A particularly sensible question in anatomy, where the supply difficulties of 'raw' study material – human corpses – and its problematic conservation, always was a problem. The implications of the developments in anatomical visualization go however well beyond matters of mere practicality: Tomàs Maldonado, who has investigated the relationship of approaching the study of the human body through the physical and virtual dimensions stresses, in one of his essays, how since Vesalius, the visual medium started prevailing as the way to document the direct investigation of human's anatomy: "*the vision embraces the task of documenting, illustrating graphically the acquired knowledge. Predictably, the primacy of vision becomes the primacy of the image*"[4].

By the turn of the 18th century, the wide availability of printed literature based on a solid iconographic apparatus, attests two interconnected facts that are very interesting to us. The existance, of course, of a proper industry of knowledge, from printers and publishers, to students, educators and scholars; and the emergence of a new market for culture, made of a new



kind of public – that sorrounding Vesalius himself in his great volume's frontispiece, as well as in many other anatomical theatres around Europe – made by intellectuals, informed citizens, the curious. A growing community, hungry for visual media, that not only fed that very industry, but greatly contributed in fostering the dissemination and sharing of the new knowledge itself as a model for the development of scientific thought.

About one hundred years of medical studies later, a series of groundbreaking medical discoveries finally started to turn the work of physicians and surgeons into something practically useful. Empowered by a new degree of interest by contemporary mass-media medicine, now an increasingly popular profession and a discipline that improved people's lives, was to radically change its status.

In this new atmosphere medical studies where experiencing a significant growth throughout Europe and in the US. Henry Gray's 1858 *Anatomy, Descriptive and Surgical,* most widely known as *Gray's Anatomy*, is an important milestone along this path. Originally conceived as a practical reference for medical students, the volume was extremely successful at its time becoming a long-seller sensation[5]. The book's editorial fortune is connected with a winning combination between its superb

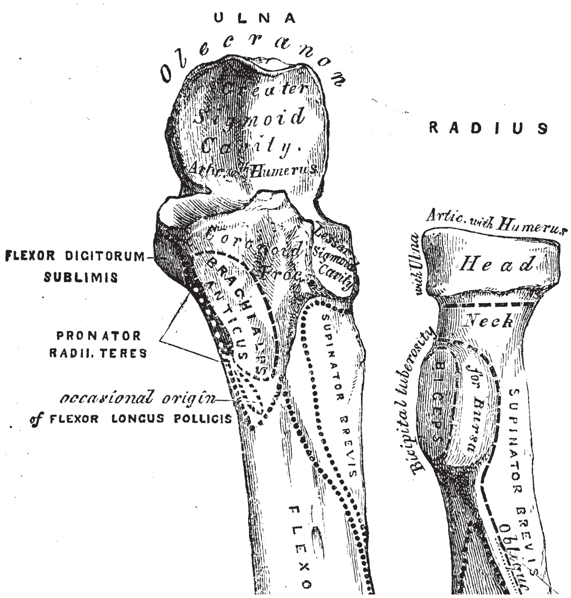


Fig. 4.

The head muscles, from Henry Grey's *Anatomy*.

Fig. 5.

Bones of Left Forearm, plate from *Grey's Anatomy*. Among the many stiking features making Grey's volume the prototipe of a modern scientific book was the arrangement of text labels and notes and their reference to the illustrations.

illustrations, a small handy format, and a very accessible price. Although technically less sophisticated that those of many concurrent books of its time, based on metal-based engravings, Gray's xylographic illustrations, masterly executed by the book's co-author Henry Vandyke Carter, displayed remarkable visual clarity and effectiveness. Marking a new standard for anatomic illustrated atlases, the book's iconographic apparatus was not only more numerous and larger than before: it reached a degree of excellence that, as it has been pointed out, "*brought anatomy into the realm of exact sciences*"[6].

Things our eyes don't see: technology

As we have seen, the development of procedures to graphically record, represent, and eventually disseminate, the findings of scientific advancement is a key component of the scientific method itself. Another crucial factor in this evolution is the interaction between the developments of scientific investigation and technology advancements.

Thanks to new findings in optics, and to the related technical improvements in glass making and cutting, starting from the 17th century worlds otherwise invisible to the bare eye suddently became the object of new explorations, recordings and visualizations. Through the telescope, equipped with an appropriate set of lenses, Galileo Galilei was able to improve his observations of the sky, documented by a series of extraordinary watecolour sketches that still are a key reference in scientific visualization. Meanwhile, through different arrangements of lens, other scholars were able to direct their investigations to a domain of totally different scale, that of the microscopic dimension. In his 1665's *Micrographia: or, Some physiological descriptions of minute bodies made by magnifying glasses*, Robert Hooke, the natural philosopher, architect and member of the Royal Society, unveiled memorable magnified visions of insects, plants and other natural marvels.
On the way to modern knowledge, the connection between technology and scientific research, would fully manifest two centuries later when, in the so-called 'age of progress', mankind embraced a major endeavor to filling the remaining uncharted territories of science.
The work of the French physiologist Etienne Marey is a perfect example of the positivistic tension of its time towards knowledge. Marey devoted his life to a tireless quest, exploring ways to measure and study a variety of physiologycal phenomena. As early as in 1850 he began developing his *Méthode Graphique*, a sophisticated system based on new scientific instrumentation that enabled him to track phenomena associated with human's physiology, in order to translate them into visual records. The Spygmograph, the first of the many

measuring instruments devised by Marey, converted human wrist's pulses into a graph, by charting them through a stylus and a clockwork mechanism. The ingenuous arrangement, by translating the pulses to a trace on a paper strip previously darkened with smoke, "*transformed the subjective character of pulse feeling into an objective, visual, graphic representation that was a permanent record*"[7].

Years later, Marey's interest in motion brought him to embrace the newly introduced technology of photography. As it has been noted, he "*wanted to arrive at a visual description of the common types of human motion-the walk, the run, the jump, and so on-and the forces at work in their execution... but this required a less abstract visual representation than his graphic method could provide*". In order to record movement from actual models, and through a painstaking fine tuning of photography techniques, the French physiologist developed *cronophotography*, a solution that allowed him to record motion, in form of multiple expositions, shot at regular time intervals on a single film plate. This research eventually led him, through the production of some of the most iconic images of scientific progress of his century, on the whereabouts of the invention of cinematography itself[9].

The true 19th century's crucial step in making the invisible visible is, nevertheless, Wilhelm Röntgen's discovery of the X-rays.

In 1895, while experimenting with cathode rays in his laboratory, Röntgen, a Professor of Physic at the University of Wurzburg, litterally bumped into his great discovery. As he was operating his equipment Röntgen observed the presence of unknown rays that, as he would later recall, appeared to be "*coming from some sort of invisible light*". Over the following six weeks, the German scholar went on a thorough exploration of this phenomenon, ending up with an extensive scientific

report which he steadily shared with colleagues from leading research intitutions of the time. Having used photo-sensitive paper to record the properties of the new rays, Röntgen was able to capture several images, among which the X-ray picture of his wife's hand: "*since the rays had this great penetrative power, it seemed natural that they should penetrate flesh, and so it proved in photographing the hand*", he would later declare. The picture, which he included, among others, in his report, showed for the first time the bones' internal structure behind the human flesh: an instant demostration of something bound to become a practical and life-saving diagnostic tool. The "*discovery of rays that could penetrate the body and photograph its bones"*[10], was a breakthrough in showing the invisible, making the human body increasingly transparent, and leading the way to new, technology-centered, approaches to medical inquiry, that rapidly became of public domain.
Since the introduction of X-rays the idea of interpreting images for diagnostic purposes – collected through different means – of the otherwise invisible inside of our bodies, has taken a pivotal place in medicine. Technologies we are today very familiar with where actually generated by this idea: *Ultrasound Ecography*, introduced in the medical domain in the late 1940's by Ludwig, and further developed by John Wild; *Computer Tomography*, as the follow-up of research by Godfrey Hounsfield, resulting in the first *CAT* scanners in 1972; *Magnetic Resonance Imaging*, that was successfully used on living human subjects from 1977. None of these imaging technologies is actually based on images in the terms we traditionally think of them: they analyze and scan our bodies to gather information through various technical procedures and process the data translating them, through "imaging", into their real-time visual representations. Computer Tomography (from the Greek *tomos:* section or slice) for instance, combines X-ray data of cross sections of a human body, digitally processes them and stacks the individual

slices one after the other, to create three-dimensional representations of internal organs. *MRI* uses a similar process, but has replaced the invasive X-Rays with information obtained by analizing variations in magnetic fields.

Things our eyes don't see: getting deeper

The publishing of Vesalius' main atlas was soon followed by a smaller edition of the original volume, the *Epitome.* Thought as an introductory and practical aid to its larger companion and as a summary for students, the volume was "*Organized so that two of the plates could be cut out and re/assembled over the skeleton figure as a 'flap' anatomy following the popular 16th century tradition of fugitive sheets*"[11]. The book invited readers to cut and assemble the different elements according to the instructions provided[12]. Pretty much like our children's paper-dolls, flap or 'fugitive sheets' were large sheet paper models meant to be cut-out and arranged in assemblies. In pre-modern medicine, these sort of instruction-kits were used as "*guides by barbers, surgeons, and bath attendants*"[13], those who, despite lacking any theorical preparation, 'practiced' in fact surgery before it became a properly established discipline. Items of marvel somewhere between science and entertainment, fugitive models, and to some extent the *Epitome* itself, were also affordable commercial items, a marketing solution directed to a growing public. Nevertheless the wide distribution and popularity of flap models indicates the demand for ways to represent the human body that could overcome the flat two dimensional of a printed page, partially supplementing the lack of actual models.

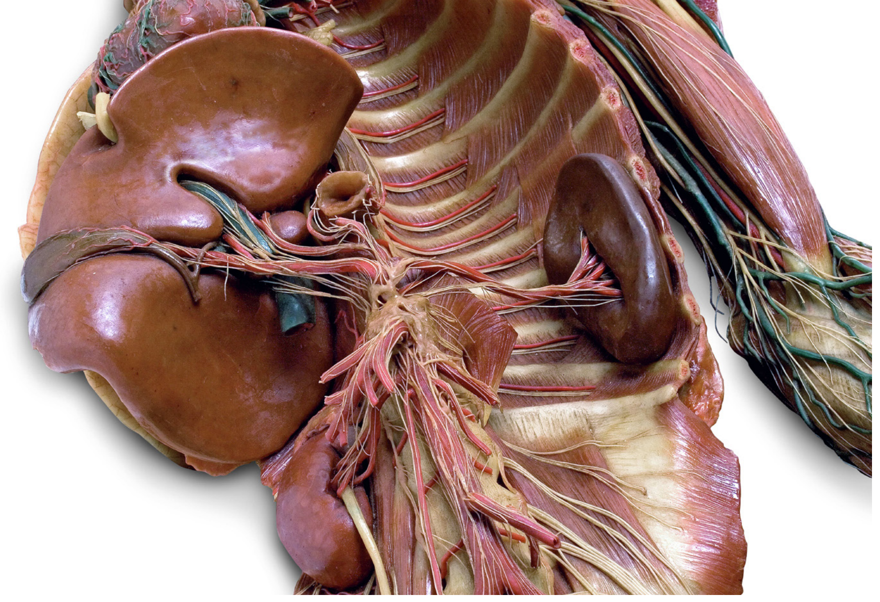


Fig. 6.
Clemente Susini, wax anatomical model.

Various means for recording and transmitting anatomical and medical knowledge: physical models of the human body and organs, in different scales and materials, including ivory, wood, papier-mâché, ceramic, and of course paper, have been constantly present through the history of medical practice. Among them wax: a material that, for its malleability and its capacity to vividly render the nature, color and appearance of skin, muscles and organs, has a long tradition in anatomic modeling.
Wax models had been in use for a variety of scopes ranging from devotional religious items, *ex-voto*[14] to marvels in gallery popular attractions of the kind of London's Madame Tussaud's. Their use for the production of anatomical study models for medical institutions around the world grew of importance between the 18th and the 19th centuries.

Early examples of wax anatomical models can be found at the end the 17th century in work by Sicilian abbot Gaetano Zummo, whose baroque wax tableaux portraying vivid allegories on macabre human post-mortem decay are a classic in their genre. Although very little is known about Zummo's life, it appears that at some point he moved to northern Italy.
Bologna, then a leading centre in scientific research and medicine, was house of one of the first anatomical theatres. Here, the local University established a workshop aimed at produc-

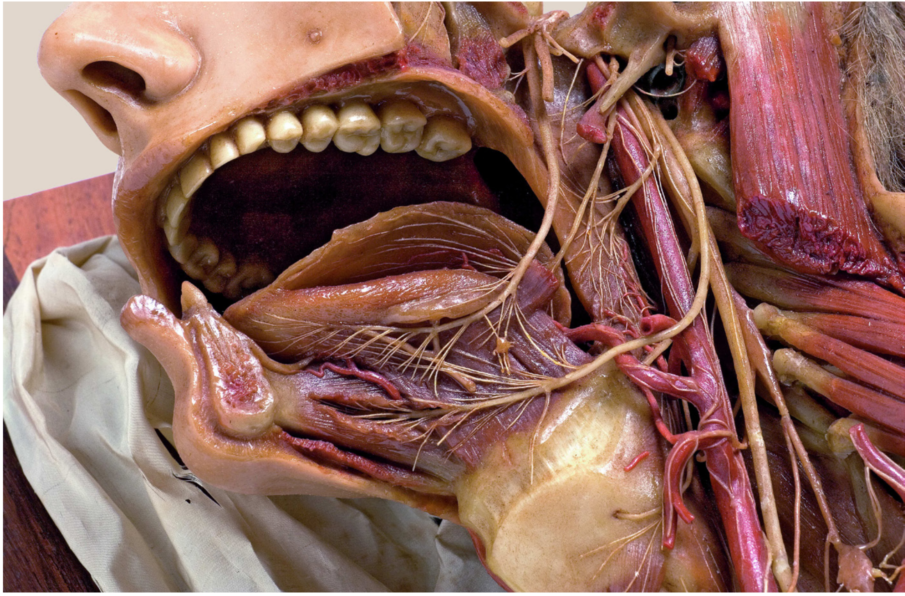


Fig. 7.
Clemente Susini, wax anatomical model.

ing high quality wax models for the study of anatomy. There Ercole Lelli and after him his former collaborators, Ercole Manzolini and particularly his wife, Anna Morandi, took the craft of wax modelmaking to standards of excellence.
In nearby Florence another wax modelshop was started at the *Specola*, the nucleus of the local Natural History Museum, by its first director, Felice Fontana. Here over the years, either for the local collections or for first-class external institutions, Clemente Susini, one of the finest ever wax anatomical modelers, created masterpieces that became well-known and extremely sought-after throughout Europe. Samples of his work are still on display in scientific museums such as the *Josephinum* in Wien, or at the University of Cagliari, in Italy, as well of course, as in Florence.
The remarkable longevity of wax anatomical model collections, such as those developed by Susini at the *Specola* and by his British colleague Joseph Towne at London's Guy's Hospital, and the fact that they have been in use for the study of anatomy until not too long ago, is the best possible demonstration of their practical utility.

Some recent approaches to the three-dimensional documentation and representation of anatomy, that are in many ways a modern development of the legacy of 18th and 19th century anatomical wax collections, are certainly worth our attention.

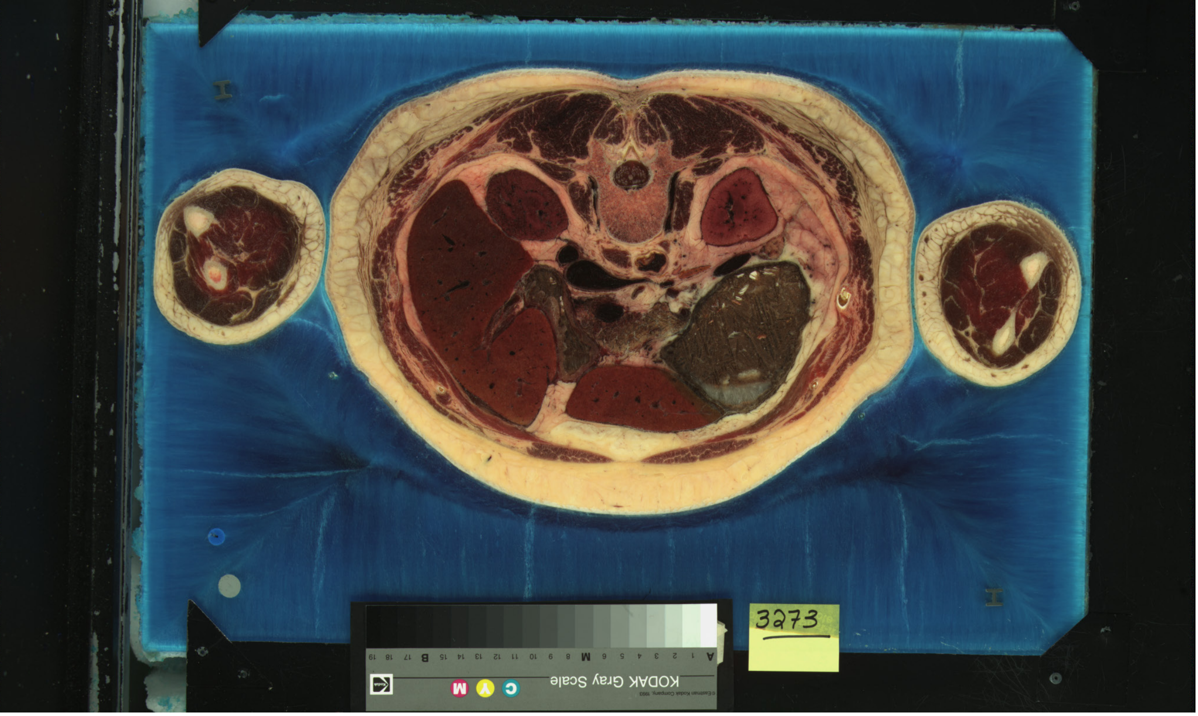


Fig. 8.

The Visible Human Project.

The *Visible Human Project*, (1989-1995) is a re-visitation of the idea of the anatomical atlas. In track with the advancements in digital technology of the 1990's, the system stored a multimedia data-base on an interactive disc. Carried out by the U.S. National Library of Medicine, the project was aimed at creating *"complete, anatomically detailed, three-dimensional representations of the normal male and female human bodies (...) to produce a system of knowledge structures that will transparently link visual knowledge forms to symbolic knowledge formats such as the names of body parts*".

In order to set up a data-base of more than five thousand pictures depicting actual cross-sections of the human body, the bodies of two volunteers, frozen after their death, where crio-sectioned axially (one section for every millimeter for the man's body, three for the woman's body). Once digitally scanned the data-sets could be interactively explored, in fact 'played' like a movie, so that the user could literally go through the two bodies. Although made possible through digital technology, the resulting representation of the actual sections of the two human bodies is one-hundered percent "real".

Another more recent approach, in fact what must be considered as the state of the art in the study and documenting of anatomy, is virtual reality anatomy, which takes today place on accurate 3D models, which can be accessed interactively in real-time. VR exploration offers great flexibility, so that scholars, physicians and students can practice on detailed three-dimensional models, arranged in sets and layers, not only exploring the model spacially, but also with varying levels of detail. Moreover, the different systems, organs, layers and so on, can be selectively switched on and off to allow, whenerver needed, the study of each system in isolation.

Things our eyes don't see: design

At the end of the 19th century Atlases like Christian Wilhelm Braune's *Topographisc-anatomischer Atlas* (Atlas of topographic anatomy), exemplify the state of the arts in anatomic iconography at its analog and pre-photography climax. Almost one hundred years before the project we have just discussed, the volume's colour plates presented detailed hand-drawn actual sections of frozen cadavers, offering an extraordinarily sharp depiction of the human body. From the 1880's, the introduction of photo-engraving techniques, and shortly after of photographic reproductions – standard features in scientific books by the beginning of the following century – combined with the great detail made possible by full color representations, common by then in professional printing, brought anatomical illustration to unmatched degrees of realism.

Interestingly enough though, as the combination of a higher scientific understanding of the human anatomy and the emerging of technologies for visualizing it had allowed to reach astonishing results, realism *per se* begun losing its desirability. The emergence of groundbreaking imagery, such as photography and X-rays started having an impact on anatomical documentation: the available degree of detail, often in form of non-filtered information, was now producing too much information.[15] Most unexpectably, tecnological advancements were making things more difficult to understand than ever, at least in the domain of medical dissemination. This state of things generated a shift of interest from the increasingly available realistic and detailed imaging to the more schematic and abstract visualizations associated with the skills of professional scientific illustrators[16]. The ability of selecting and synthetizing information or, in other terms, the "*cognitive interpretation of an image*"[17], was being now acknowledged as an increasingly relevant quality. In a way, this helps explaining the success of the detached and neutral visual approach of *Gray's Anatomy'*s illustrations and, much later, the work produced over a very long and celebrated career, by Doctor Frank H. Netter.

As we move into the Twentieth Century, we must consider the coming into play of a new fact: the popularizarion of medicine. Emerging success stories, such as Pasteur's vaccine against rabie or the battle against Yellow Fever, contributed in casting new light on the medical practice. A growing interest towards health and the history of medicine in the emerging popular media opened the way to a general favorable atmosphere towards science and technology, medicine. The new attitude demanded, of course, a novel approach: introducing, presenting and illustrating, medical knowledge to an expanding completely new kind of audience, required adequate languages and techniques. A public less and less made of medical pratictioners, that wasn't much interested in the meticolous, objective, realistic, and detailed representation of the human body and that was instead interested in getting the general picture and in being entertained.

Rather than more detailed and punctual explanations this state of things demanded for a totally new approach opening the way to new keywords like selectivity, storytelling and design.

Although, as we shall see, this vast program in medicine popularization would follow a variety of directions through many different channels, for the last time in our story, the starting point will be, once again, books.

The extensive and succesfull editorial production by Fritz Kahn is a landmark on the path to medicine popularizarion. A German physician with a versatile personality, from the late Twenties of last Century to his death in 1968, Kahn devoted himself to making the secrets of the human body accessible to the general public. In his long and prolific career Kahn authored a series of innovative illustrated volumes[18], directed to a domestic audience that was increasingly interested in medicine and health issues.

Playing a role somewhere between the editor and the art director Kahn, who relied on the collaboration of professional artists and illustrators to picture his books, explored ways to translate abstract, invisible, and complex phenomena in widely accessible forms. His main contribution to medical dissemination is possibly the visual language he developed to bring medical science's key concepts to "the guy next door".

In terms of visual style, whilst being obviously rooted in the legacy of anatomical iconography, Kahn introduced new formulas combining unconventional visual approaches and innovative storytelling strategies. Through an extensive use of classic rethoric devices, such as visual allegories and analogies, Kahn translated scientific facts into every-day examples anyone could relate to, eventually succeeding in making complex

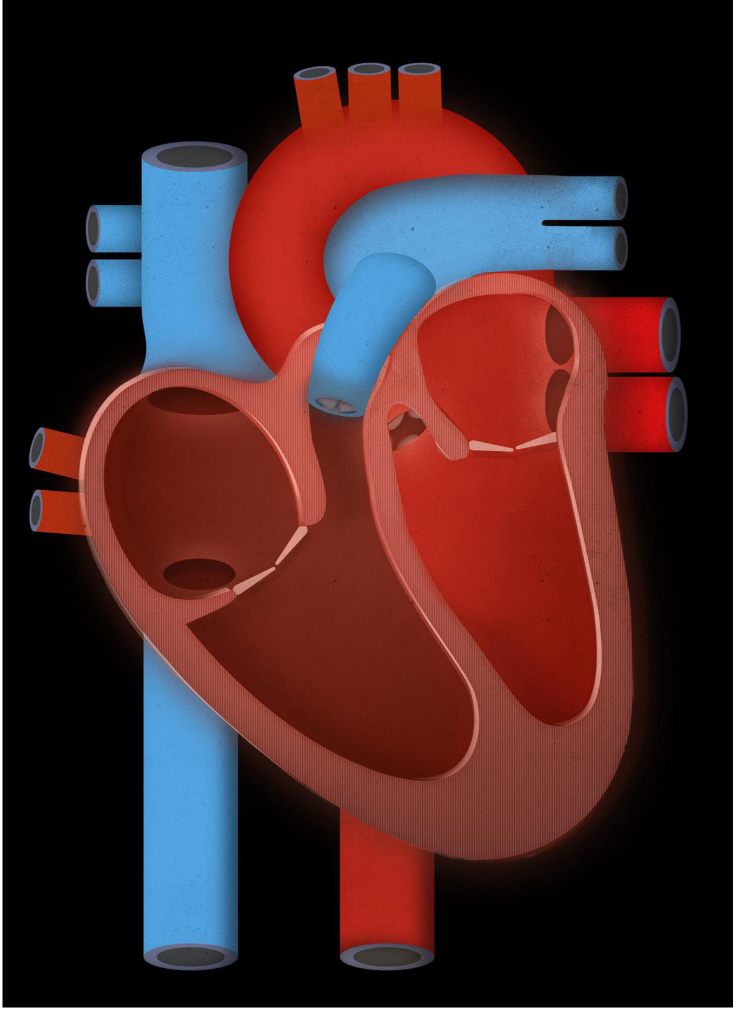


Fig. 9.
K. Anderson, the heart. Courtesy of Kelli Anderson/Tinibop

concepts not only appealing, but widely understandable to the general public.

A valid example of this approach can be found in the analogy – constant throughout his entire work – between the human body and the machine. Along this track, food is presented as the fuel that makes the engine of our body-machine work. Human senses are frequently presentend in association with technology, in terms of the connections between sensory stimulation and brain reactions: cinema for sight, telephone for hearing, and so on. The heart then can be presented as a pump, capable of moving the elevator of a multi-storey building (up to five floors in 40 minutes!). To depict the daily growth

of human hair, a single 30 meter hair is convoluted in spiral form around the image of a woman in something reminding of a cage.
Often Kahn also exploited radical visual solutions. A plate on "The effects of solar rays", in 1939's book *Der Mensch Gesund und Krank II*, reminds the modernist style of Bauhaus-like photo collages.

Fritz Khan's main contribution to medicine popularization possibly relies in his ability in exploiting the power of imaging well beyond its capacity of depicting reality *per se*. In what is one of his more popular and iconic anatomical allegorical plate: 1926's *Der Mensch als Industriepalast* (Man as Industrial Palace), the human body itself becomes a factory: a palace-machine where all elementary physiological functions: vision, hearing, taste, and so on, are associated with their possible "industrial" correspondent. The resulting image, although probably too over-simplified, is a beautifully crafted artifact of great visual power.
Either he received credit or not by the many books, diagrams and illustrations that his work inspired, the visual model Fritz Kahn established in his books[19] has strongly impacted scientific illustration, becoming a solid model for scientific dissemination, medical and not. Not by chance his work has been recently re-discovered by the info-graphic design community, which in its right considers Fritz Kahn contribution's in scientific visualization and in making complex phenomena understandable absolutely pioneering.

Another noteworthy step on the way to modern medicine popularization can be found in the work of another German-born graphic designer, Will Burtin.
Just like Kahn, Burtin fled Germany following the uprising of the nazi regime. In 1943, shortly after relocating in New York

as an illustrator and a graphic designer, he joined the US Army to enroll, as many other professionals coming from the field of visual design, in one of the military communication branches involved in the production of informative/training material. The Office of Strategic Services (OSS), the division in which Burtin served during the war, gathered a number of graphic designers, art directors, advertisers, photographers and people from the movie business, some American-born, others, as in Burtin's case, European expatriates, working side by side[20]. As it has been noted, at that time, the OSS "*may have been the most creative design shops in the U.S.*"[21]. The experiences and professional exchanges that took place in units of this kind were in fact to play a pivotal role in the development of American visual design itself for the years to come.

After the war Burtin became Art director of Fortune, a position that allowed him to hire some of his former wartime fellow visual designers, as well as other european expatriates, such as Herbert Bayer, Ladislaw Sutnar and Max Gschwind. To present technical and science-related topics, Fortune extensively explored new ideas and lay-outs – large informative spreads, maps and illustrated diagrams – and in fact, these post-war years experiments can rightly be seen as pioniering examples of infographics. Burtin eventually left the magazine to start a life-long collaboration with UpJohn, a major pharmaceutical company, for which he art-directed the monthly corporate magazine, *Scope* and took care of a variety of other in-house promotional publications and activities.

Starting from the 50's the post-war economic boom brought companies throughout the world (Olivetti in Italy, IBM in the US, to name two very well known cases, or CIBA in the US and Geigy in Switzerland, in the phamaceutical field[22]), to invest in major corporate communication activities, resulting in the pro-

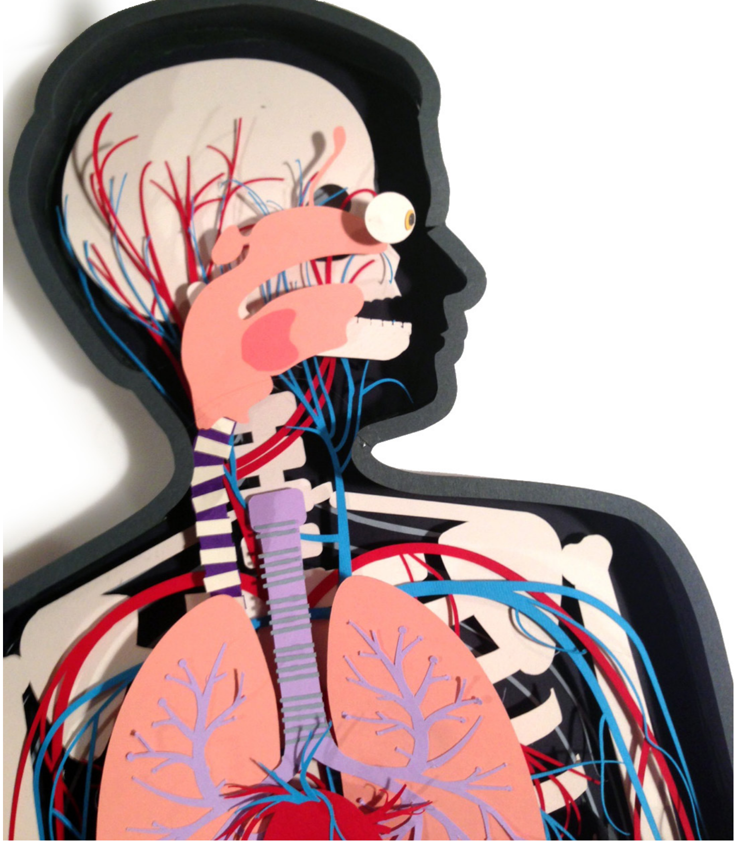


Fig. 10.
K. Anderson, paper anatomical model. Courtesy of Kelli Anderson/Tinibop

duction of vast amounts of informative material and advertisement. The program at UpJohn included sponsoring large events and developing scientific-related exhibits, in medical conventions, corporate fairs and international expositions. Whithin these new promotional territories, Burtin advocated new forms of corporate activity: the development of large-scale, three dimensional physical installations that combined graphic design, spatial *mise en scene*, special effects and early multimedia.
Fairs and conventions where at the time major public events, attracting large number of visitors, enjoying massive media coverage and hence providing massive promotional opportunities. Large numbers of people could be contacted, corporate material could be distributed. This meant a tremendous opportunity to explore new ways to disseminate science and medicine (and incidentally, to promote the sponsoring corporation). Having pioneered the idea of informing while entertaining, the walk-in exhibits Burtin designed for UpJohn in the

following years must be considered absolute milestones in exhibit design and public scientific dissemination.

Burtin's first project, *the Cell*, was unveiled in 1958 at San Francisco's American Medical Association annual Convention. The result of accurate scientific research and of a fruitful collaboration with scholars and specialists in the field, Burtin's installation presented its public with an integrated exhibit concept, in which metaphorical physical arrangement, early interactive technologies, theatrical presentation and sophisticated visual design, where cleverly orchestrated to offer a unique and memorable experience. Although originally intended as an ephemeral installation, the success generated by *the Cell* convinced Upjohn's executives to turn the project into a travelling-show that, over the coming years, would be displayed in several locations around the world. A smaller copy of the exhibit went to Europe, where it became the object of two BBC specials, before traveling to Edinburgh and Amsterdam. Back in the US, the exhibit event went to Disneyland. Over the following months, in New York, San Francisco and Chicago only, more than ten million people walked through Burtin's design. So new projects followed.

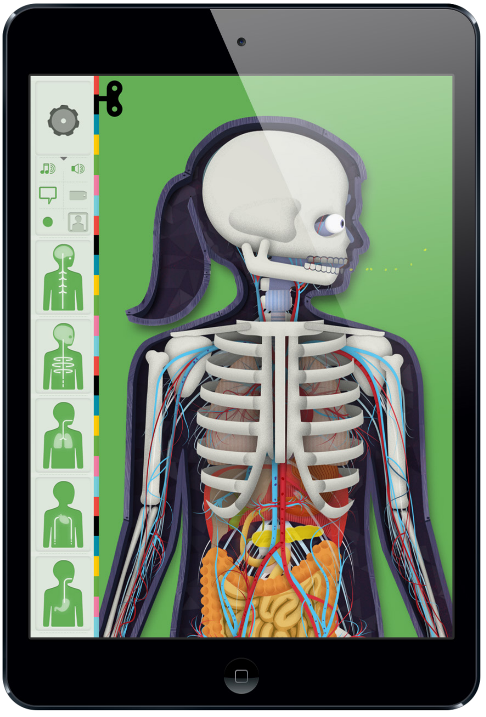
The Brain, presented in 1960, focused on demonstrating the workings of the brain associated with the two senses of sight and sound. It presented a multimedia show, run by electro-mechanical controllers derived from telephone switching equipment, arranged in a methaporical setting: "*the cell resembled what it represented. But it was more important for* the Brain *to demonstrate mental function rather than to resemble the actual organ*'[23].

Further successful Burtin-Upjohn exhibits, such as *Metabolism* (1963), *Genes in action* (1966) and *Defense of Life* (1969), paired other notewhorthy design activities Burtin developed in the field of scientific popularization, as the finely illustrated volume *Story of Matemetics for young people*, designed for Pantheon in 1966[24].

Things our eyes don’t see: penetrating the human body

The explorations in scientific dissemination in the work of Fritz Kahn and Will Burtin where welcomed by the atmosphere of growing interest towards medicine we have already mentioned. In his interesting book on the relationship between mass media and the ways in which medical progress has been pictured[25], Bert Hansen not only arguments the role played by widely successful books like Paul de Kriuf’s 1926 *Microbe Hunter,* but highlights how this trend went “*far beyond newspaper stories, hardcover books, paperbacks, and the new ‘pocket books’ that became extremely popular in the 1940’s”*. Medicine and medical discoveries became the subjects of radio programs, comics, Broadway plays and, as we have seen, major public exhibits. Even Hollywood did its part responding to the new wave by producing a number of films based on historical reconstructions of the great achievements in medicine.

Although the moving image’s revolutionary relevance in the 20th Century has been widely discussed, the role played by film in bringing a variety of scientific-related contents to a vast public is a still largely underevalued research area[26]. As a matter of fact, as soon as the motion picture started proving its efficacy as a vehicle for technical and scientific dissemination, a whole industry of sponsored, industrial and educational films, started blossoming. Various players such as publishing houses such as Enciclopaedia Britannica or McGraw Hill; national governmental organizations, UK’s Central Office of Information and many others; commercial film-production companies, universities, independent organizations and large corporations, started exploiting the new medium. This resulted in the development of a variety of educational, corporate, sponsored, material and products on scientific and technical topics[27]. The



language of cinema, its format and distribution channels, was soon welcomed as a proficient vehicle for disseminating health and medicine-related subjects too.
As we shall see, within this framework, animation was to play a pivotal role.

A first convincing explanation of the successfull *liason* between animation and scientific dissemination can be found in a 1949 article by two prominent figures in British animation: John Halas and Joy Batchelor. In their essay the animator duo – who, among many other things, worked extensively in the field of sponsored and scientific films – discusses animation's particular flexibility in showing the abstract and the invisible[28]. More specifically, Halas and Batchelor introduced this peculiar attribute as "penetration", a device they would extensively make use of within a long and celebrated career in various of their health-related films.
In 1946's *A Modern Guide to Health*, an informative film for the British Central office of information (COI) of the Ministry of

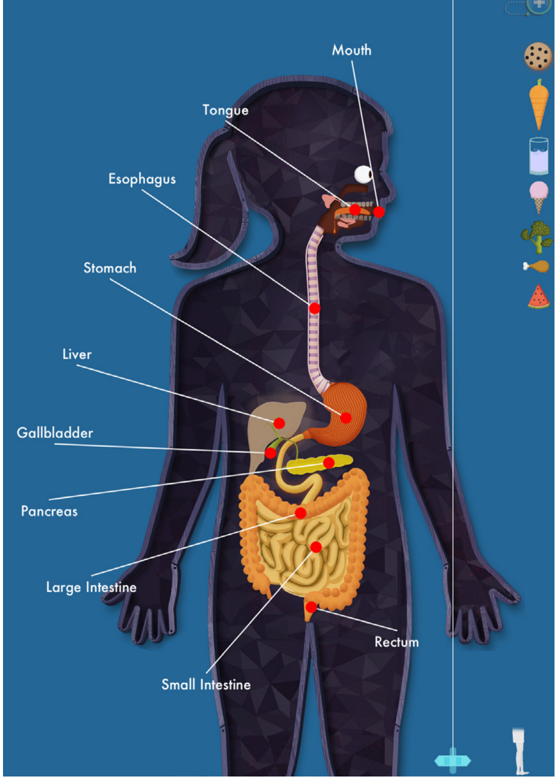


Fig. 11 and 12.

Kelli Anderson, illustration for *The Human Body App.*
Courtesy of K. Anderson/Tinibop.

Health, Halas and Batchelor combine cartoon-like sequences with "outlined" graphical technical explanations. In order to present a closer look into the body, a zoom-like effect is used to isolate anatomical details. In a following sequence an X-ray-style see-through effect illustrates, through a schematic reproduction of the body interior, a sample of the correct back posture while seating. A similar visual trick appears later where a see-through effect is exploited to penetrate a foot to depict the internal bone structure in relation with the shoes. The same idea of penetrating the human body returns in two later Halas and Batchelor films. In *Dying for A smoke*, an 1967 animated film on the dangers of smoking, produced again for UK's COI and for the Ministry of Health, a fictional doctor warns the main character, a reckless teenage boy, on the health risks associated with smoking. As the doctor continues, providing statistics on smoke victims and enumerating the associated conditions, the image of a male body is presented against a black background, while schematic animated representations simulate the way heart, lungs and other organs may be attacked by tumors.

Whereas John Halas and Joy Batchelor deserve full credit for helping in shaping and in defining, with their article and work, this peculiar application of the versatile language of animation, this idea itself wasn't certainly new: the same very concept had been extensively explored by many animators and directors before then. More recently, Paul Wells has returned to the potential of this communicative approach as he stated how: *"one of the outstanding advantages of the animated film is its power of penetration. The internal workings of an organism can easily be shown in this medium.*" Wells continues: "*The depth's of a man's soul is more than a phrase to the animator: it can also be a picture"* [29].

Through penetration hence, animation presents itself as an outstanding vehicle for medical dissemination: a powerful mean to stage imaginary journeys through the human body, framing the presentation of invisible or abstract scientific phenomena.

Nevertheless, our interest in this peculiar presentation quality goes beyond the capacity to make the invisible visible. As we shall see animation is also a very useful tool to set up coherent and believable narrative platforms.

A rather common element in informative films about health is a live action setting. The story often begins with a doctor, visiting a patient in a clinic or lecturing a small crowd in a classroom. Filming actual actors in a believable setting, helps building a realistic athmosphere. The overall scientific tone is often reinforced by a voice-over commentary providing the audience with contextual information. Typically, as the story develops, animated sequences are introduced to visualize some scientific phenomenon. The doctor himself, sometimes with the assistance of a helper turns to some technical instrumentation, a microscope or an X-rays screen. The introduction of technology not only acts as a validator of the physician's authority, but works as a narrative device: a classic solution in traditional storytelling, where is described as the “magic agent”,[30] its function is to allow the audience to see something otherwise invisible, in this case to the naked eye. Switching to animation allows a smooth conceptual shift, where the audience is transferred to another dimension, often arcane and abstract, but made believable and to some extent understandable.

Graphical animated inserts are also often superimposed to live action shots or photographs. This allows to empower the ‘realistic’ photographic look of live-action by virtual, schematic, integrations that help the audience seeing (“penetrating” in some way) abstract, or invisible phenomena. *How the Fires of Our Body Are Fed: A Study of the Human Digestive Process*, is a soundless black and white medical film from 1926. An early, though rather sophisticated, film integrating a variety of solutions, including animation, to present internal visions of the human body. In the style of some of Fritz Kahn’s allegories, the film opens with a metaphoric association between the engine of an Ocean Liner, and the human body (“*that most perfect machine*”, as the voiceover remarks). The parallel is presented in two consecutive shots, depicting the fuel that both “engines“ – the ship’s furnaces fed with coal, and a factory worker, feeding himself by eating a sandwich – need to in order to operate.

The sequence turns swiftly to a side vision of the worker chewing his food: see-through outlines of the man’s mouth and palate are superimposed to dinamically visualize the process of eating. Many other similar effects follow to present other aspects of the digestive system’s workings: animated arrows, textual captions and labels describe organs. Superimposed over a real X-ray image of a torso, an animated “magnifying lens” effect is used to introduce some micro-photography footage. Similar schemes and repertoirs of solutions

are standard features in many other films. In 1940's *How the Eye Functions*, part of the "Knowledge Builders" series, produced by the American production company Bosse, animated sequences combine accurate anatomical reproductions and cut-outs of the hearing system with schematic depictions of how mechanical vibrations are turned into impulses and sent to the brain. The film, in a way, is a logic cinematic version of the kind of effects provided by ancient flap anatomy.
Despite belonging to the domain of formal scientific and anatomical visualization, the two films we have discussed encorporate solutions that use animation to depict abstract concepts, presenting the workings of the human body in a way that is believable for the audience. This adaptability in blending different visual styles and languages in a coherent ensemble to support the association between the "real" and the abstract, is one of the most remarkable traits of penetration.

Nevertheless the ways in which animation has been put to work for depicting the abstract and the invisible go well beyond this matching capacity: the very same audiences that found acceptable the superimposion of an abstract outline diagram on a mock-up human organ, have been ready to find believable enough even cartoonish images, characters and worlds, considering them as good as the "reality" of this abstract invisible early visualizations.

Produced in 1950 by Cascade Pictures of California for the US Armed Forces Special Weapons Project, *Medical Aspects of Nuclear Radiation* is a propaganda film aimed at minimizing the threat of a nuclear war among the American people.
As in the examples we have discussed earlier, the film combines a live-action storyline with scientific-looking animated inserts, such as those presented to depict radioactive rays as they propagate in case of a nuclear explosion.

One of the film’s sequences though follows a different approach. An airbrush-painted human torso, used in an earlier scene to present a diagrammatic visualization of a radiation attack, is recycled to house a comic cartoonish sequence. The earlier technical-looking style, based on blinking dotted lines and diagrams, makes now space to a team of animated dwarfs operating a piece of machinery to depict vital bodily functions. Given the film’s general pseudo-scientific climate, this combination between Fritz Kahn’s “Palast” metaphors and the patterns of exaggerated animation may seem at first odd and slightly out of place, but in fact, the introduction of humoristic cartoon gags in informative films is everything but uncommon[31]. Many films dealing with awkward topics such as nucelar radiations, poisonous diseases, war, deadly weapons, and so, have resolved to the language of animation to soften the atmosphere, making uneasy messages more appealing to the public. But there is more than that. What is particularly relevant in our line of reasoning is that animation can not only ease a believable transition from real to abstract in terms of technical, it can even transcend reality.
On this track, as long as the audience finds the shift believable, the function of presenting a specific medical condition can be performed by a cartoon doctor character, and abstract phenomena can be made more understandable through antrophomorphism, so that human organs can become engines or machinery operated by muscle men, or even dwarfts, and, and so on...
In narrative terms, this approach allows to give shape to a framework that is far more flexible than that defined by the “realism” of live action, greatly stretching the range of storytelling options.

In what is an undisputed scientific dissemination classic – Frank Capra’s “Science Series” TV specials, produced by Bell

Labs – 1957's *Hemo the Magnificent* the serie's most medical-oriented episode, takes advantage of a wide repertoire of solutions and narrative devices to presents how circulation works in the human body.
Conceived as a family show, the film makes large use of cartoon-based inserts, gags and amusing situations, which, as for other films directed by Capra, are masterly orchestrated with a variety of visual explanatory material: graphical and schematic or beautifully illustrative animated inserts, scientific footage and micro-photography.
Capra's sophisticated narrative construction seamlessly distributes roles to cartooon-characters as well as to actors in flesh and blood: the film's main storyline revolves around the confrontation between the two show's live-action hosts and Hemo, the main animated character. A variety of additional animated characters, such as "Great Professor Anatomy", who introduces the audience to the heart's functioning through a memorable funny and imaginative sequence, make their appearance whenever needed.
In the context of the film's unconventional and rather inventive narrative structure animation provides a degree of logical continuity needed to combine and blend characters, atmospheres and contexts that pertain to totally different domains. In this respect, animation acts as a sophisticated conceptual mediator, associating the abstractness of formal scientific illustration (in our case that of anatomical visualization), schematic info-graphic-like illustrations, the "realism" of scientific photography and live action, bringing seamlessly different storytelling trajectories under the roof of the same TV show. The result is a very well designed, entertaining, informative, funny and robust audiovisual product.

Knowledge journeys

Although not covering in strict sense any medical topic, one of the unquestionably most ingenuous scientific informative films ever produced, *Powers of Ten* by the American designers Ray and Charles Eames, also deals with the abstract and the incommensurable.

A pioneering piece of multimedia communication, "*Powers*" is a very sophisticated visual journey: in fact a cornerstone of information design. The Eameses explored successfully the potential of animation in a variety of scientific dissemination projects. Animated diagrammatic sequences introduced technical details of Polaroid's instamatic camera in the promotional short *SX-70*. For their IBM sponsored exhibition *Mathematica: a World of Numbers…and Beyond* the Eameses produced a memorable series of two-minutes "peep-show" cartoon shorts demonstrating key mathematical postulates. Another IBM sponsored film, *A Computer Glossary* masterly combined cartoon sequences and abstract diagrams to present the importance of boolean logic in computing.

For their informative journey about the "*dimensions of time and space*"[32], a far more ambitious project, the Eameses pursued a different approach. The eight-minutes film is based on an elementary logical and visual frame, composed by several pieces of information presented toghether. The main "screen" section, provides visual feedback to the narrative development in form of the landscape we woud see from a camera, or from a starship's porthole, during our imaginary journey. Various "dashboard" elements – what we would today describe as an interface – encircle the central screen, "*a dashboard with several clocks shows the total distance traveled, the power of ten achieved, the traveler's time, the earth time, and the percentage of the speed of light*[33]."

The images displayed to the audience are in fact entirely virtual: reproduced in large format plates, being either photographs, photo-collages or abstract artwork, they were produced and assembled “in-house” by the Eames Office. Once coupled with the abstract numeric data presented by the “interface”, these discrete elements provided extraordinarily effective visual clues and a strong narrative backbone to the presentation.

The journey starts with the photographic detail of the wrist of a man resting on a blanket, in the intimate and familiar setting of a picnic at the park. As the imaginary camera starts moving out the man becomes a tiny dot, gradually disappearing as we zoom out to the city’s centre, the whole region, the planet. The camera keeps moving backwards and we soon find ourselves in space: the tiny dot in the center of the frame is now that of planet earth. Out of the solar system, a previously familiar landscape gives space to the dark and empty environment of far away stars and galaxies.
The film’s conceptual highlight lies in the effect achieved by juxstaposing an extremely abstract representation of the events’ progression – the figures and data on the dashboard dials, the detached voiceover – with a consistent and believable visual sequence. In his seminal article about the Eameses’ work, Paul Schrader dubbed this technique as “information overload” highlighting it as a common solution consisting in counterpointing “*narration, sound effects, music and images, to present several related bits of data simultaneously*”[34].
The careful choice of images is also a crucial step: matching (pay attention to this old trick!) the familiar and visually instinctive with the unfamiliar and matematically abstract, so that they make sense of each other. The film is unarguably a masterpiece and a milestone in information design: it presents abstract and extremely complex information, thoroughly and concisely, through memorable engaging images, and doing so

it entertains the audience without losing scientificity. But, as for every piece of very fine design, there is more than that. *Powers of Ten* not only is an artifact of informative entertainment of the finest kind: it is a pledge to humanism, and a projection of a vision, that of the celebrated modernist duo – and of the US, coming out victoriously from the war – positively oriented to an idealistic future of progress.

Conclusions. A two way journey

The central pages of Vesalius' *Ephitome* portray the figures of a naked man and woman. Flipping the volume's pages allows, as the author himself suggests in the introduction, to empower the available information, exploring the invisible...As it has been pointed out[35]:*"As the reader moves backward to the first sheet, the male nude loses his skin, then his muscles, ending as a skeleton, holding a skull in a gesture of melancholic vanitas. Running from the female nude forward to the last page are separate vignettes of the vascular and nervous system to be cut and applied, again as recommended by Vesalius".*

In *Powers of Ten*'s key sequence, once having reached the farthest possible "*hypothetical point in space*" the camera stops "*and zooms back again, going through the man's wrist to the frontier of the inner atom*"[36].
The journey then runs forward, and after reaching the starting point, we zoom in the original wrist detail, go through the skin's fine patterns, to finally penetrate the human body.
Soon after, as we are exploring the dimension of cells and atoms, our imaginary journey becomes as misterious as it was before, in the desolation of the darkest space.

The center of this true *coup de theatre*, the familiar vision of a man and woman resting on a picnic cloth, closes the loop. Just as for Vesalius *Ephitome*'s Adam and Eve paper dolls, similarly to Leonardo's Vitruvius' Man.
The two-fold journey humankind had started around the 16th Century finally comes to its end.

notes

1. Harry, R., *The scientific Image, from Cave to Computer*, New York, Freeman & C., 1993, p. 40.

2. Rifkin, B. A., Ackerman, M. J., Folkenberg, J., *Human anatomy. Depicting the body from the Renaissance to today*, London, Thames & Hudson, 2006, p. 16.

3. Vesalius' *Fabrica* was published in Latin, the offical scientific language of the time. Knowing latin was not common: those who did where part of a cultural elite. Remarkably, being intended thought for a wider audience than its main volume, Fabrica's summary, the *Ephitome*, was originally also published in vulgar German.

4. Maldonado, T., *Critica della ragione informatica*, Milano, Feltrinelli 1998, p. 150.

5. Gray's Anatomy, celebrated its 150th anniversary in 2008, with its 40th edition. A 41st edition followed in 2015.

6. Ford, B. J., *Images of Science: a History of Scientific Illustrations*, London, The British Library, 1992, p. 44.

7. Braun, M., *Picturing Time. The Work of Etienne-Jules Marey (1830-1904),*

8. Chicago, University of Chicago Press, 1992. p. 18.

9. Marey was in strict contact with the Lumières brothers and contributed soundly to the invention of the motion picture.

10. Assmus, A., *Early History of X-rays*, in “Beam Line”, 25, (Summer 1995), p. 11

11. Petherbridge, D., Jordanova, L., *The Quick and the Dead: artists and anatomy*?, Berkeley, CA, University of California Press, 1997, p. 162.

12. Rifkin, B. A., Ackerman, M. J., Folkenberg, J., *Human anatomy,* p.125.

13. Jones, T., S.,*The evolution of Medical Illustration*. *Essays in the History of Medicine*, University of Illinois Press, 1965.

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15. Ford, B. J., *Images of Science: a History of Scientific Illustrations*, London, The British Library, 1992.

16. Kemp. M., Wallace, M., *Spectacular Bodies: the Art and Science of the Human Body from Leonardo to Now*, London, Hayward Gallery, University of California Press, 2000. p 17-18.

17. Ford, B. J., *Images of Science*, p. 45.

18. Kahn started his publishing career in Germany in the Twenties to continue it in the US after settling there to escape the nazi regime.

19. Among others, a beautiful and very popular volume aimed at medical popularization published in US in the late Fifites, credits Fritz’s Kahn work as a key source of inspiration: *The Human Body. What it is and how it works*. Golden Press. New York. 1959.

20. The contribution brought to the evolution of american graphic design by the large number of expatriates that moved to the US to escape fascism and war in Europe, is a history that still needs to be written.
See, Remington, R., *American Modernism, Graphic Design 1920 to*

1960, London, Lawrence King, 2003.

21. Remington, R., Fripp, R., *Design and Science: the Life and Work of Will Burtin*, Lund Humphries, Burlington, VT, p. 34.

22. Janser, A., Junod, B., *Corporate Diversity*, Baden Switzerland, Museum fur Gestaltung Zurich and Lars Muller Publishers, 2009.

23. Remington R., Fripp, R., *Design and science: The Life and Work of Will Burtin*, p. 88.

24. As an AIGA leading member, Will Burtin was a very active figure in the international debate about visual design. Among his many explorations of scientific popularization, his design for Pantheon's *Story of Matemetics for young people*, in 1966, deserves a special mention.

25. Hansen, B., *Picturing Medical Progress from Pasteur to Polio*, Rutgers University Press, 2009, p. 134.

26. Something I have discussed previously in my article in the IP handbook series' second volume, Ceccarelli, N., *Let's Get Abstract! The Language of Animation in Documentary Films Between Information and Narrative*. In, Ceccarelli, N., Turri, C., (editors) "Informanimation 2012. Research, education and design experiences". Milano, Franco Angeli, 2014.

27. Hediger, V., Vonderau, P. (editors), *Films that Work: Industrial Film and the Productivity of Media*, Amsterdam, Amsterdam University Press, 2009.

28. Halas, J., and Batchelor, J., *European Cartoon: A survey of the animated film*. in Manvell R. (ed.) "The Penguin Film Review", London Penguin Books, 1949.

29. Wells, P., *Understanding animation*, 1998 Oxon, Routledge.

30. These are key ingredients of classic story-telling theory I have discussed in the article *Let's Get Abstract! The Language of Animation in Documentary Films Between Information and Narrative I already mentioned.* See note 26.

31. The *Snafu* cartoon series, produced during WWII for American GI's are a very good example of this approach.

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33. Schrader, P., *Poetry of Ideas*, p. 11.

34. Schrader, P., *Poetry of Ideas*, p. 9.

35. Rifkin, B.A., Ackerman M. J., Folkenberg J., *Human Anatomy: from the Renaissance to the Digital Age*, New York, Abrams, 2006, p.25.

36. Schrader, P., *Poetry of Ideas*, p. 10.

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