FROM VESALE TO POURCELOT VIA HARVEY AND PULSE COLOR DOPPLER

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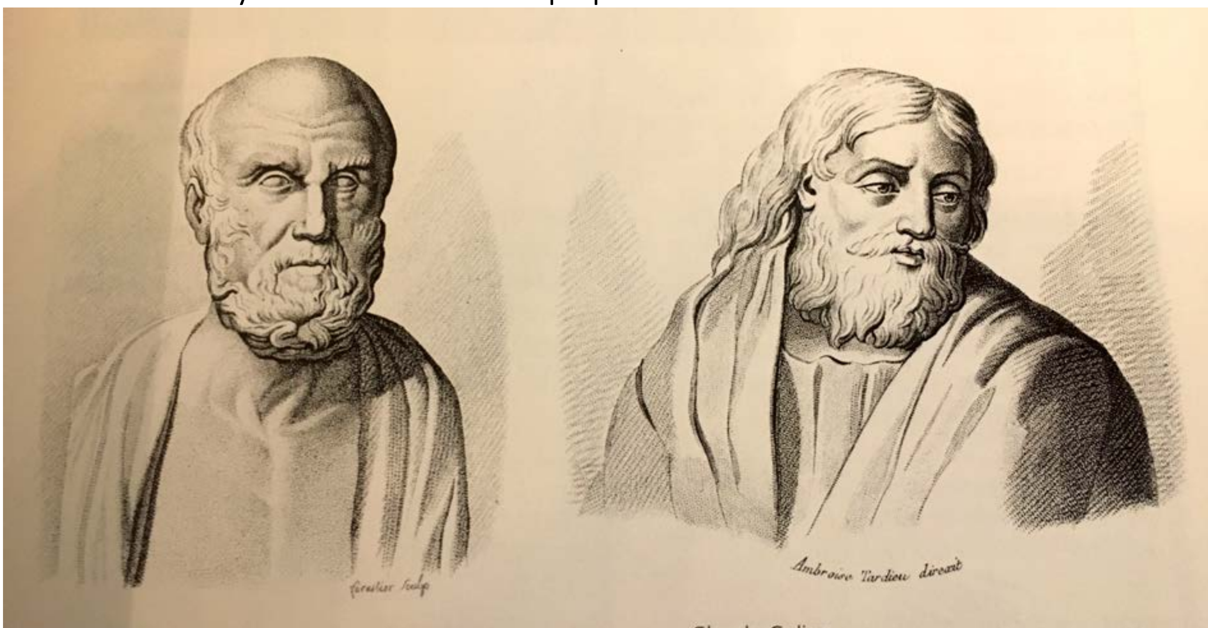
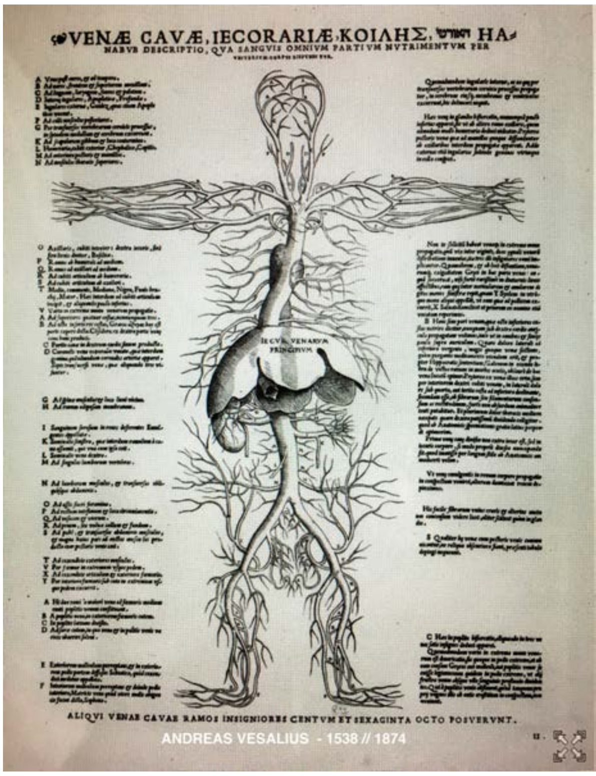
Since their origins the humans have tried to acquire the knowledge of the anatomy and of the physiology of their body. Hippocrates of Kos (ca.460 BC-ca. 377BC) was the first physician of the history of humanity when he founded the fundamentals of the clinical medicine; he learnt anatomy on the battlefields but his manuscripts were not illustrated by pictures of the body whether it was normal or abnormal. A decisive advance was promoted by the school of Alexandria headed by Herophilus (ca. 330BC to ca. 260 BC) and Erasistratus (ca. 315 - ca. 240 BC) under the dynasty of the mighty Ptolemaio Pharoahs; they practiced autopsies of cadavers and may be vivisection; whether illustrated or not, their manuscripts were burnt during the fire of the Library of Alexandria ordered by the Christian Roman Emperor Theodosius the Great (347-395); the autopsies were prohibited for centuries in the whole Christian world. So, Galen of Perganum (129 AC – ca. 200/ca. 216AC) whose philosophic activity was performed mainly in Roma remained the reference in anatomo-physiology of the humans; unfortunately, his literature was based on animal data until the Italian school of medicine more than one millennium later decided to cancel the prohibition of autopsy of the human cadavers. During that long period of time there was no illustration of the human body available for scientific purpose.

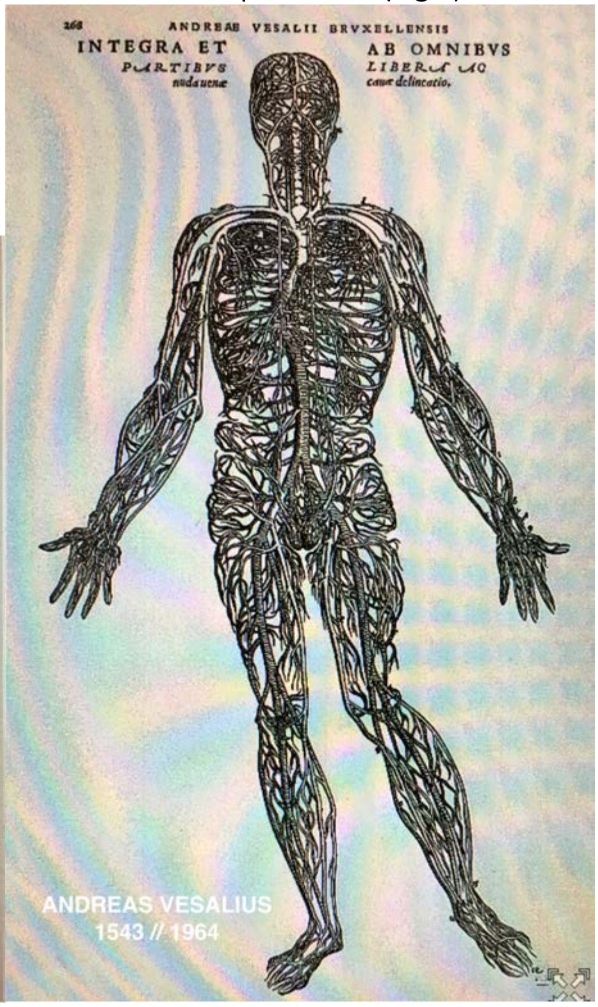


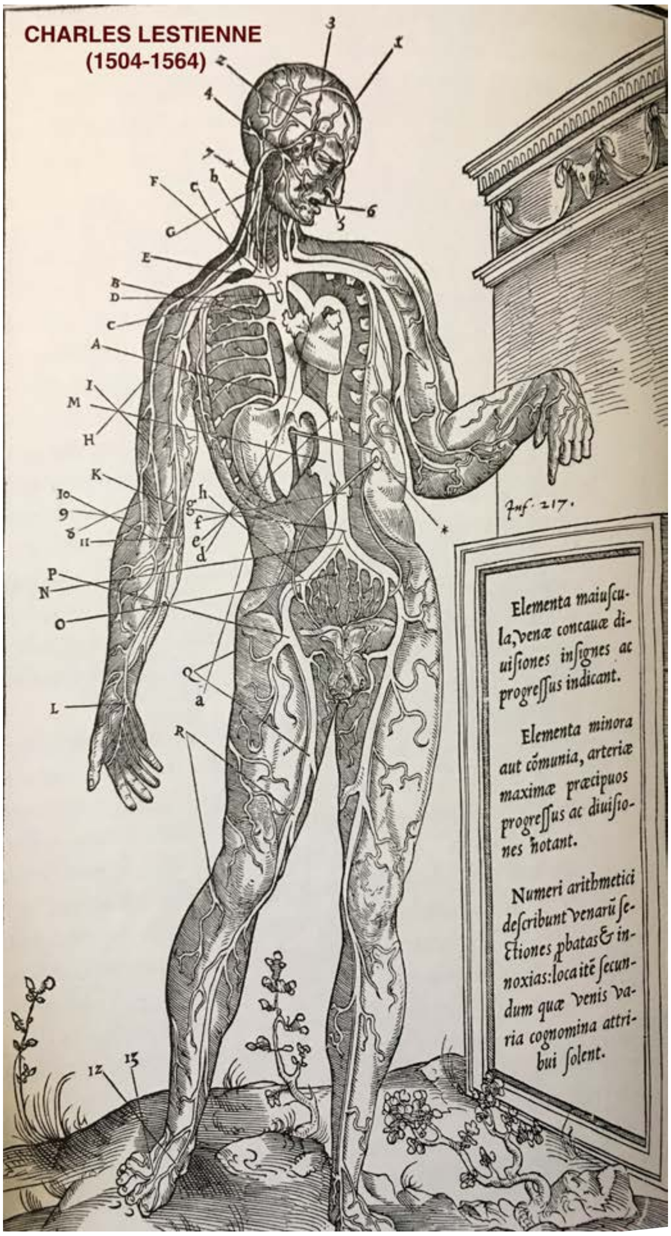
Hippocrate
(Cos, vers 460 av. J.-C. – Larissa, Thessalie, vers 377 av. J.-C.).

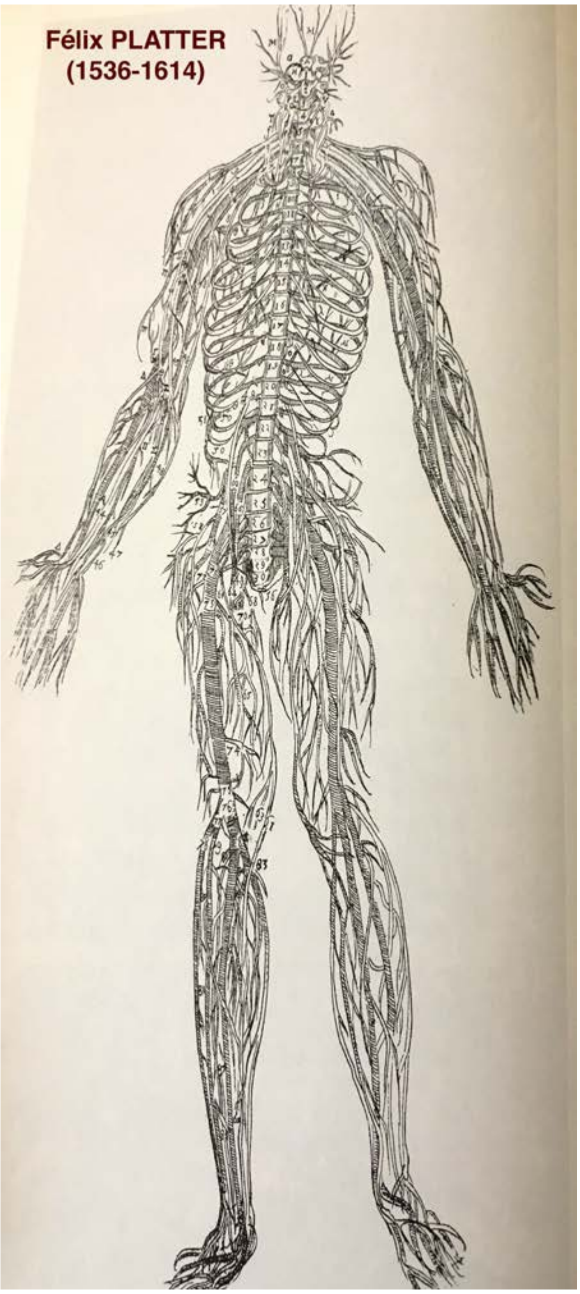
Claude Galien
(Pergame, vers 131 – Rome ou Pergame, vers 201).

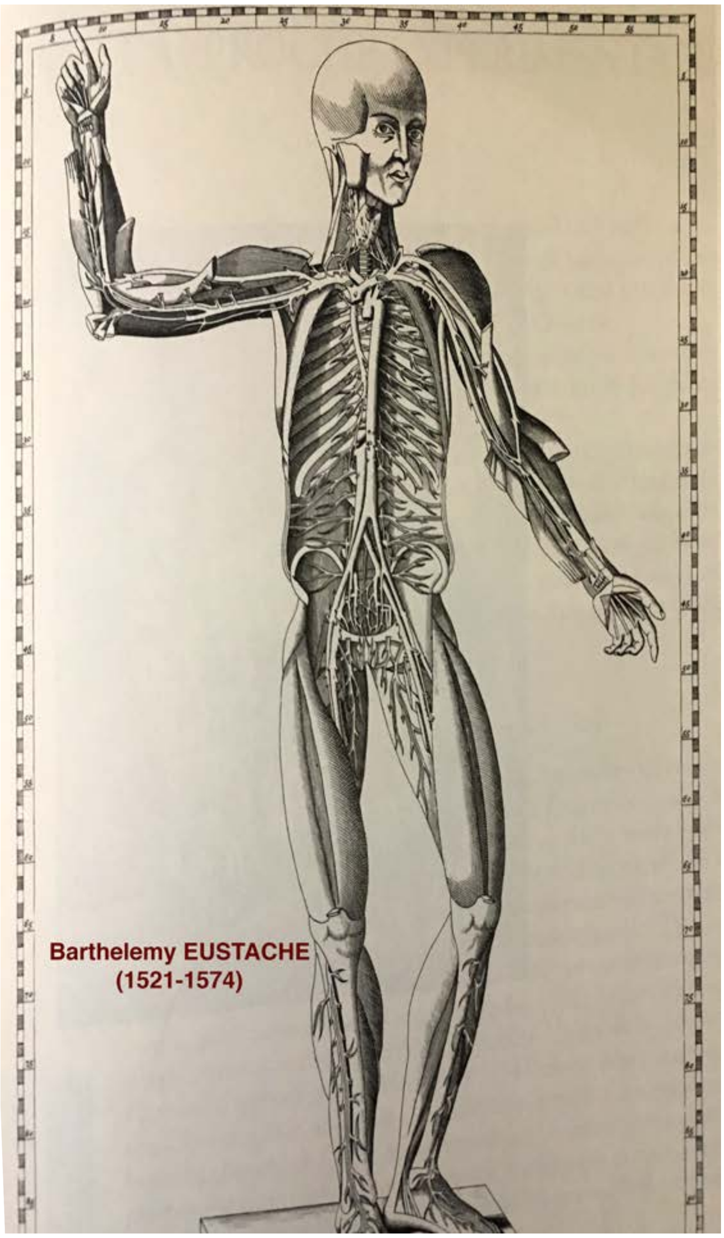
The development of the modern science of anatomy highly relies on the inventions of the paper by the Chinese and of the printing by Gutenberg (1400-1468). Now let you imagine somebody using a sheet of white paper, he can picture a piece of the body with a black pencil; this is the principle of positive illustration; conversely a teacher using a blackboard can draw the same piece with a white piece of chalk, featuring the negative view in photography extended to radiology. The first great anatomist was Andreas Vesalius of Padua (1514 – 1564); his major contribution to anatomy is the “fabrica”[i], an opus made of five volumes, the third volume of which is dedicated to the vessels and to the nerves of the body. The illustration in black on a white frame were printed with a technology termed wood engraving (fig 1.). A similar technology was used by the printers of the opus by Charles Estienne[ii] (1504-1564) (fig 2) and Bartholomaie Eustachi[iii] (1521-1574) (fig 3). Later the anatomists took advantage of a new technology called etching using a plaque of copper that gives a softer and more precise imaging; the illustration provided by the anatomo-physiologist Albrecht von Haller[iv] (1708-1777) reaches a kind of perfection (Fig 4).

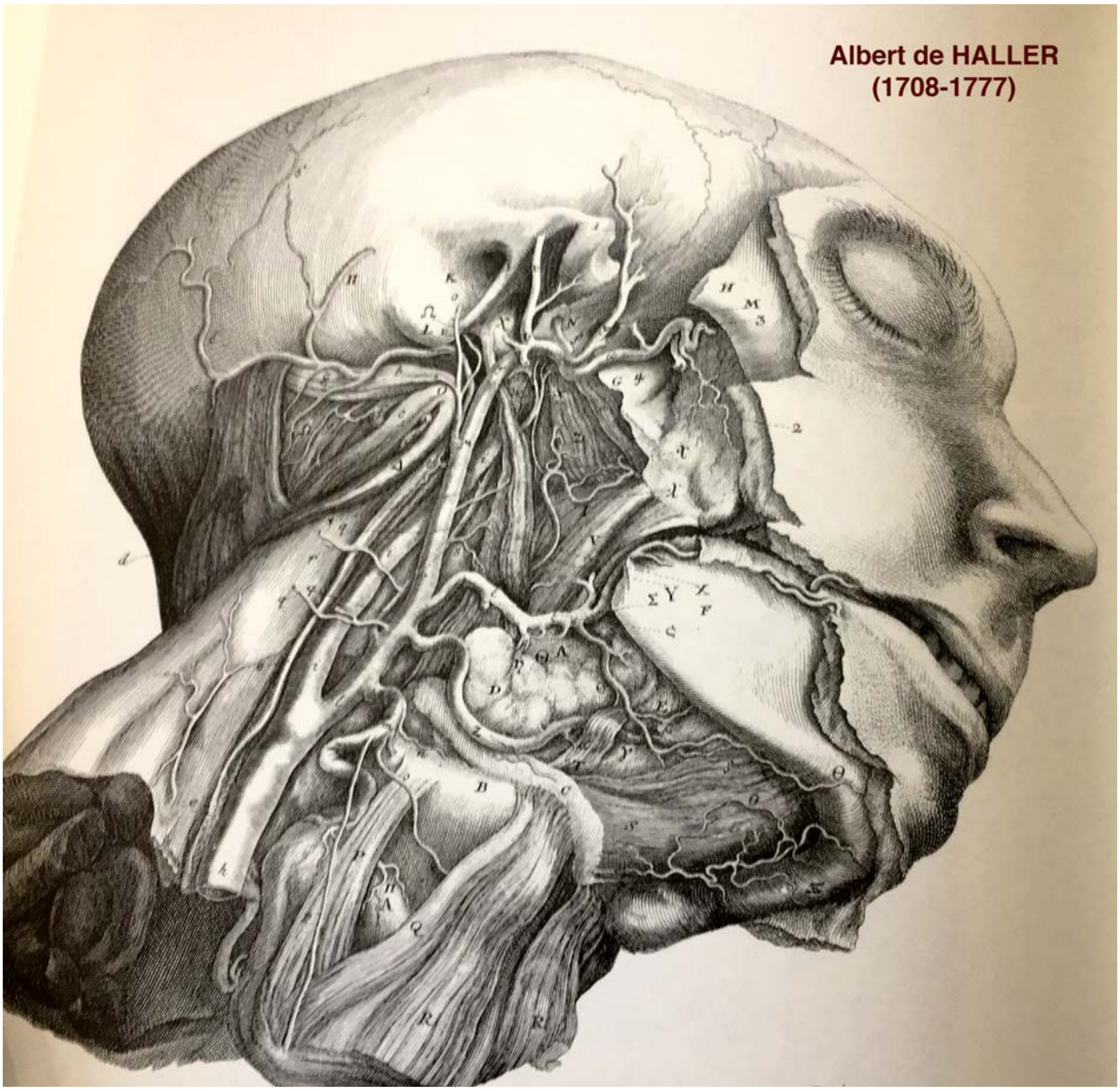




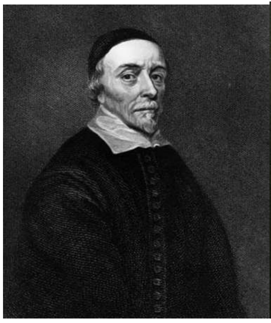

CHARLES LESTIENNE
(1504-1564)
Elementa maiuſcu-
la, venæ concauæ di-
uiſiones inſignes ac
progreſſus indicant.
Elementa minora
aut cõmunia, arteriæ
maximæ præcipuos
progreſſus ac diuiſio-
nes notant.
Numeri arithmetici
deſcribunt venarũ ſe-
ctiones ꝓbatas & in-
noxias: loca itẽ ſecun-
dum quæ venis va-
ria cognomina attri-
bui ſolent.

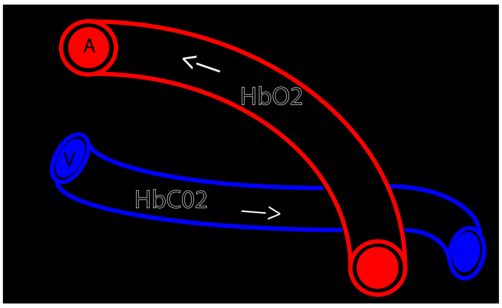

Félix PLATTER
(1536-1614)


Barthelemy EUSTACHE
(1521-1574)



The earliest anatomists were wrongly influenced by Galen[v]. The light came from a physician from the Saint-Bartholomew Hospital of London, William Harvey[vi] (1578-1657) who stated in 1628: "*It has been shown by reason and experiment that blood by the beat of the ventricles flows through the lungs and heart and is pumped to the whole body*". The evidence of distal arteriovenous shunts was demonstrated by Marcello Malpighi (1628-1694) using the newly available microscope invented controversially in 1625 by Galileo Galilei[vii] (1564-1642); Malpighi featured the arteries in red and the veins in blue[viii]; however the official colors of the pulmonary vascularization from both right atrium and ventricle to the chest through the pulmonary artery are more exactly colored in blue since the blood is coming from the caval vein system full of carbaminohemoglobin while the pulmonary veins are in red to the left atrium full of oxyhemoglobin like the left ventricle and the aorta. Since the chemical mechanism of the hemoglobin cycle was unknown at that time, this is likely Malpighi made his choice according to the colors of the blood, gleaming red in the arteries in the aortic system, much darker purple in the caval one.

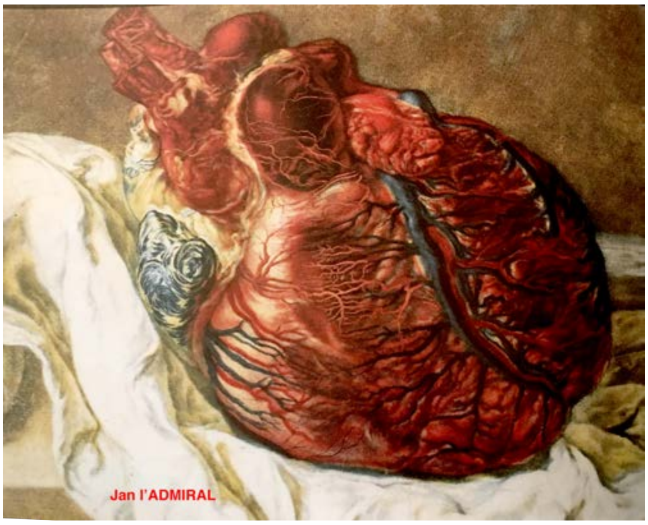


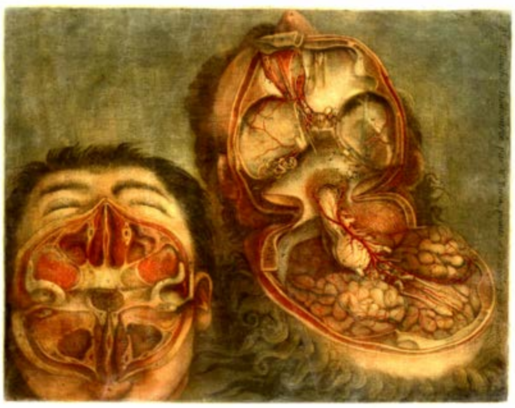


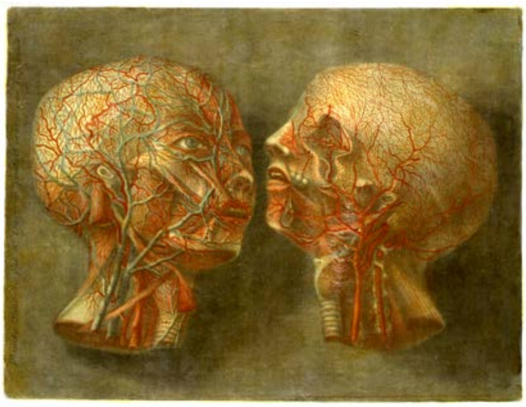
In the late XVIIth Century, Isaac Newton (1643-1727) introduced his theory of the solar light studied by prisms made of three colors: the red, the blue and the green made of a combination of blue and yellow[ix] (fig 5). A German printer, Jacques-Christophe Le Blon (1667-1741) was inspired by that theory and invented the etching in trichromacy (fig 6 & 7). His main Dutch fellow was Jan L’Admiral (1699–1773) who reproduced a famous etching of a heart (fig 8). In between Le Blon and L’Admiral, there is no doubt the third actor for the promotion of colored printing is the French Jacques Fabien Gautier d’Agoty (1716-1785) who picked the Le Blon basic trichromacy but ended by the printing of a slice of black color; the result was a better contrast of the anatomical images (fig 8 & 9)[x]. The most achieved printer was that of Paul Mascagni (1752-1815) (fig 10).

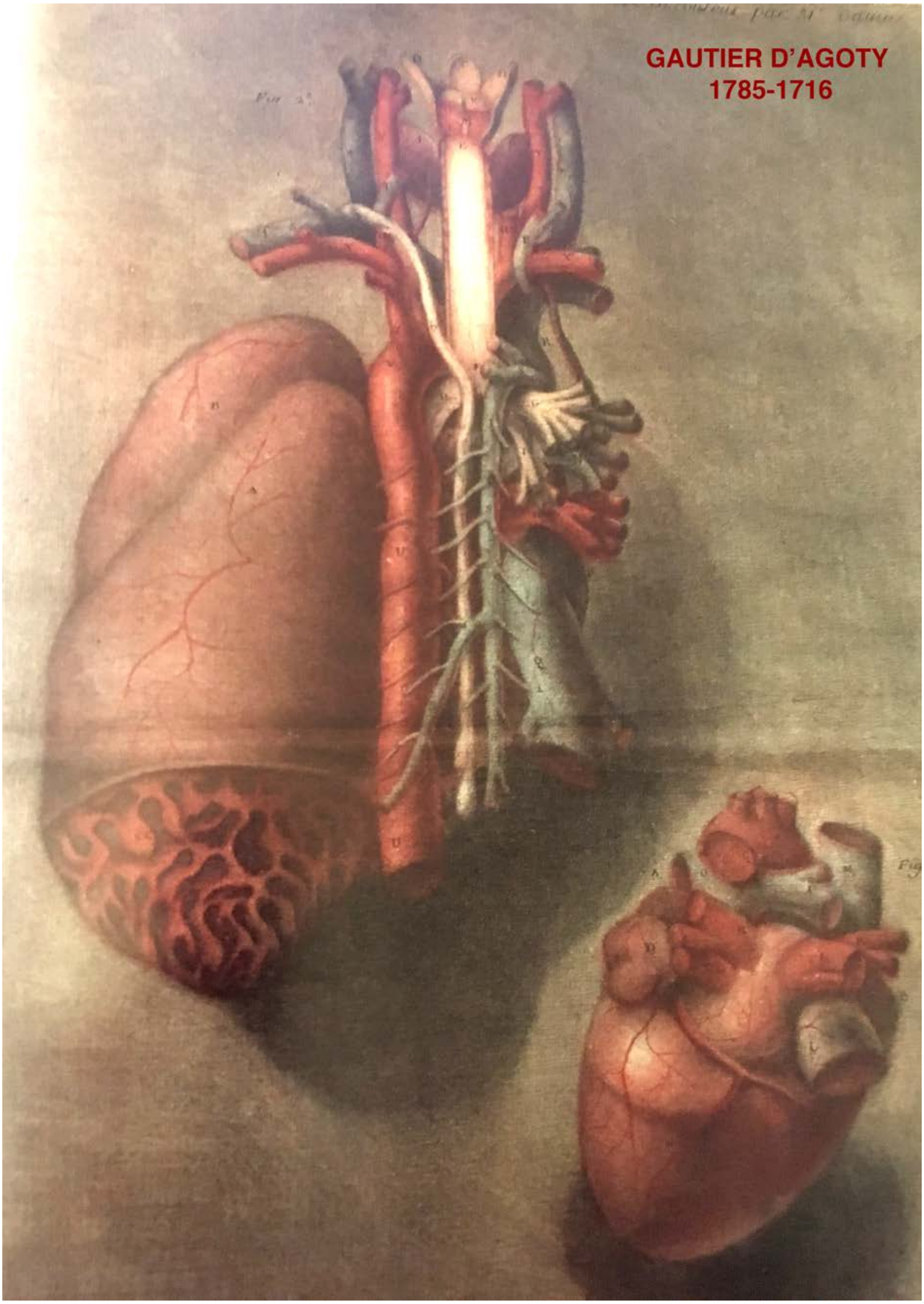
Figure 1.5 The first representation of Newton's spectrum to be printed in color. From the *Observations sur l'Histoire Naturelle* of Gautier D'Agoty, 1752.

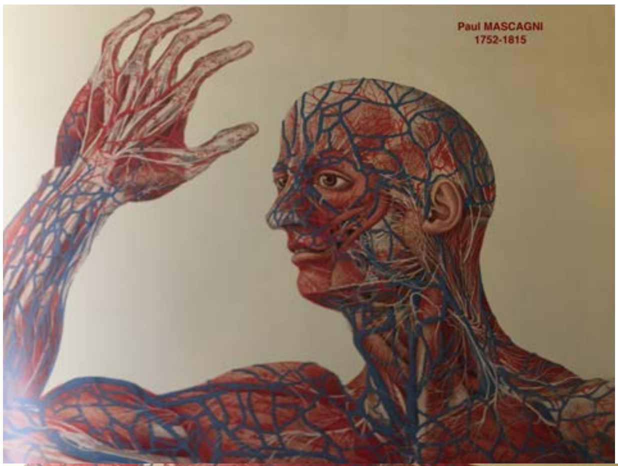

JAN L'ADMIRAL
trichromy
YELLOW
YELLOW + BLUE
= GREEN
RED


Jan l'ADMIRAL

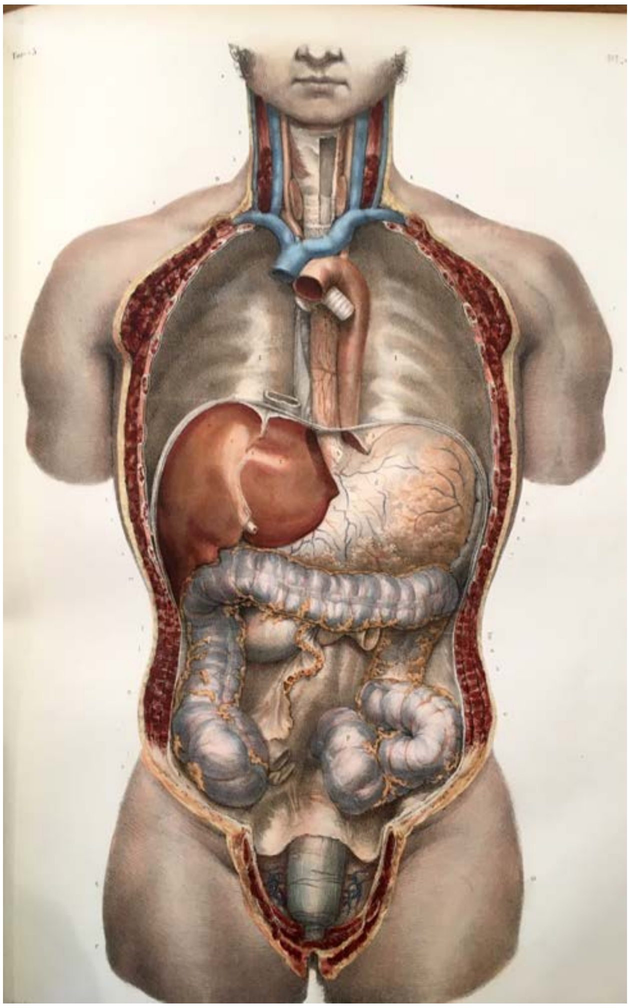


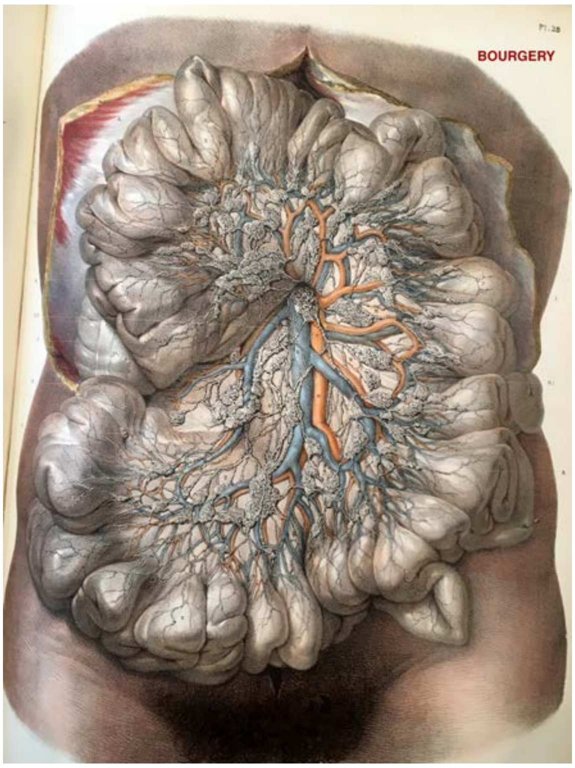


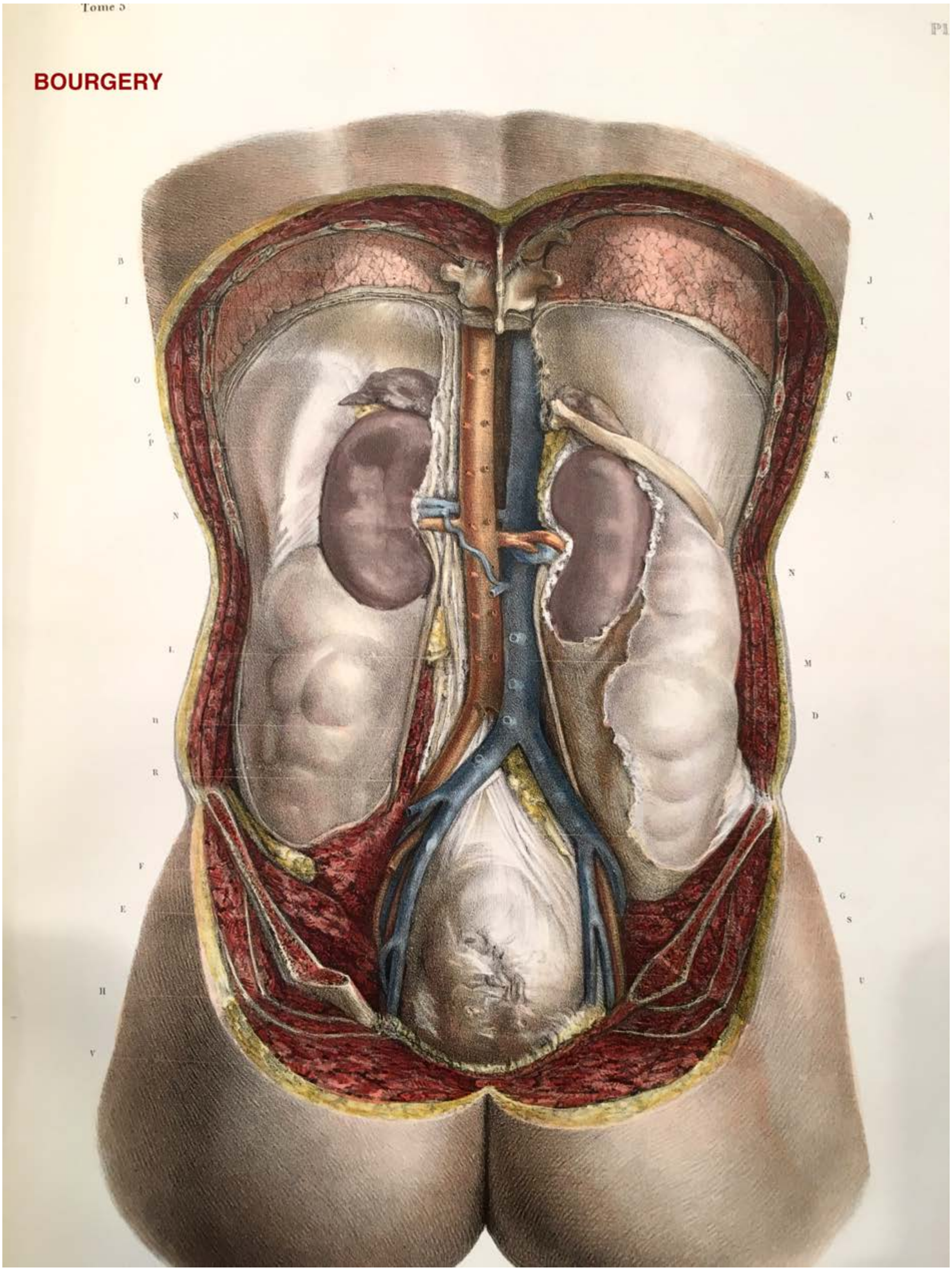

GAUTIER D'AGOTY
1785-1716

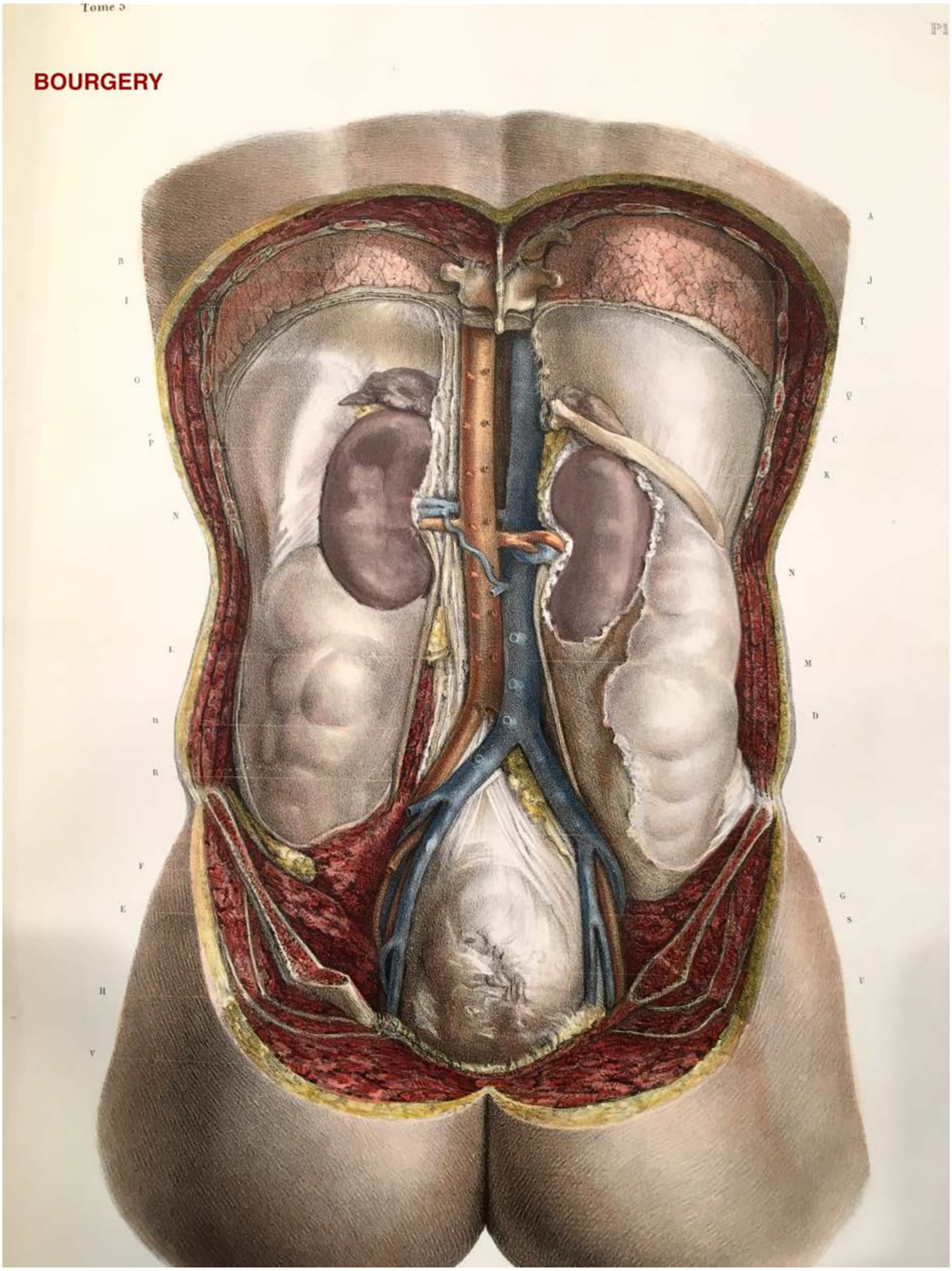


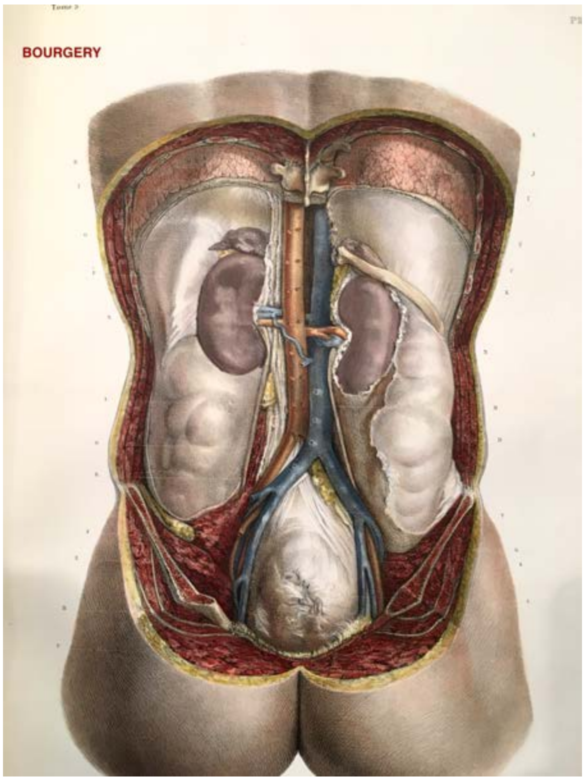
The three contemporary authors already cited in our bibliographic reference list, De Montmollin et al., Rodary and Mollon, do not mention a third technological stage in the development of etching based on quadrichromacy applied to lithography on limestones. The reason might be because their promotors didn't act as illustrators of anatomical books. The pioneer in 1792 was a German printer called Eloys Senefelder (1771-1834). He was followed in France by 1815 Charles Philibert de Lasteyrie du Saillant (1759-1849) and in 1836 by Godefroy Engelmann (1788-1839) who introduced the chromolithography in quadrichromacy (cyan, magenta, yellow, black); the latter is the first step of what it will become the offset printing one century later. The treatise of Jean-Baptiste Marc Bourgery[xi] (1797-1849), is considered by the international experts as the most impressive book ever published in the field of anatomy (fig); he was illustrated by Nicolas-Henri Jacob (1782–1871). The first edition was printed on lithography in quadrichromacy. The recent reedition by Taschen is printed in offset[xii]. Whatever the technology of engraving used, the arteries are conventionally colored in red and the veins are colored in blue in the pictures exhibiting the great circulation and conversely if this is the pulmonary circulation. The choice is less exclusive in the case of the lymphatic vessels and lymph nodes (white or yellow or even purple) and in that of the nerves (white or yellow or black).

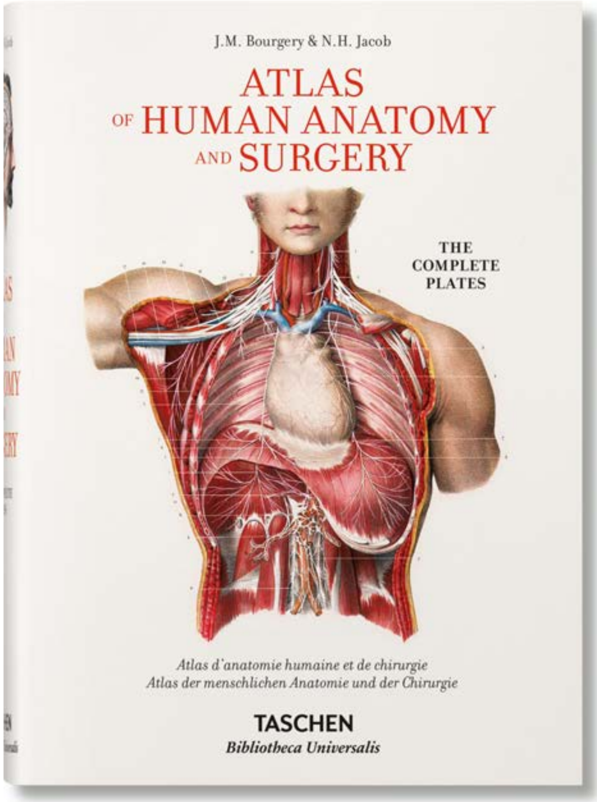


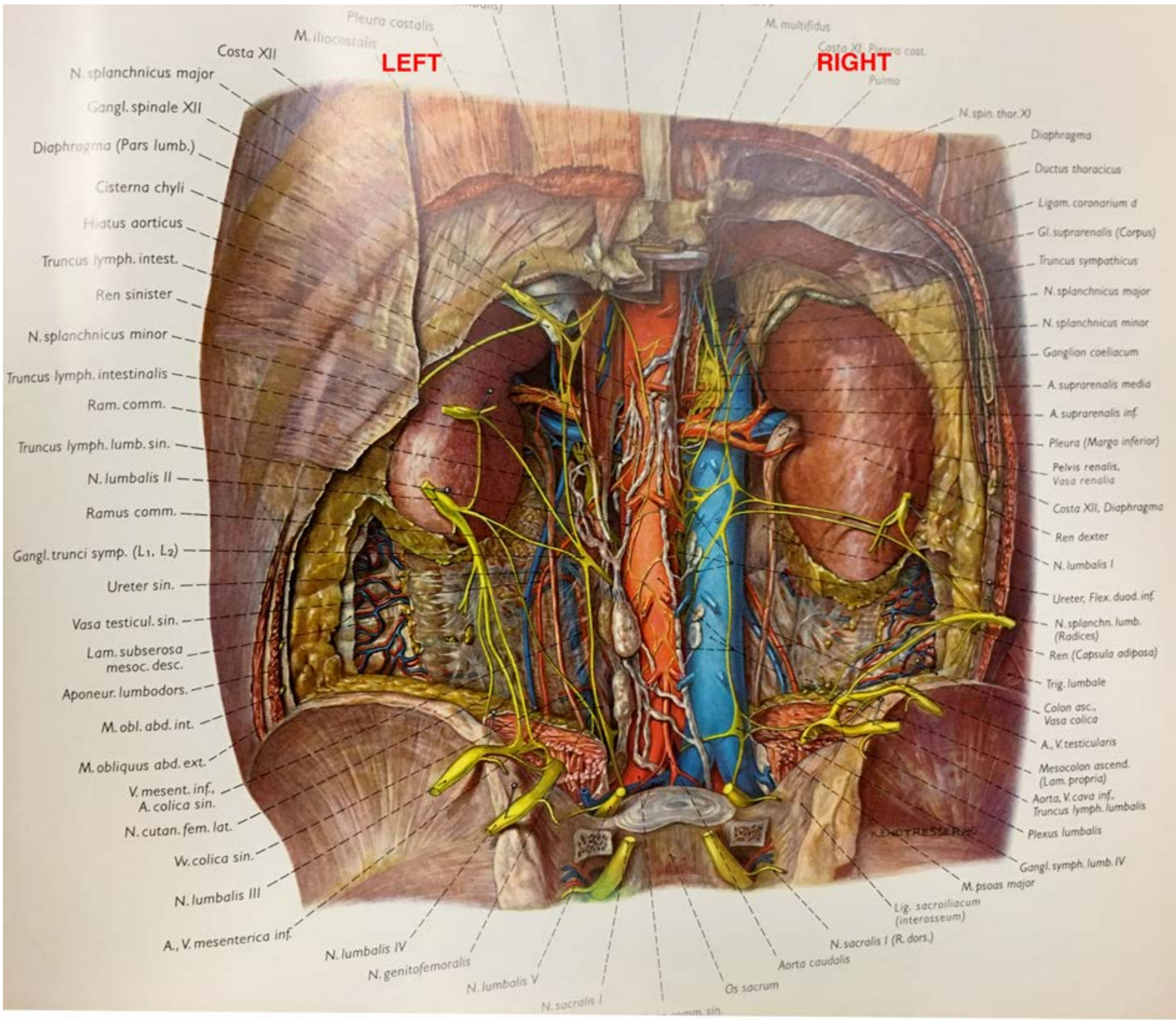

BOURGERY


Tome 5
BOURGERY

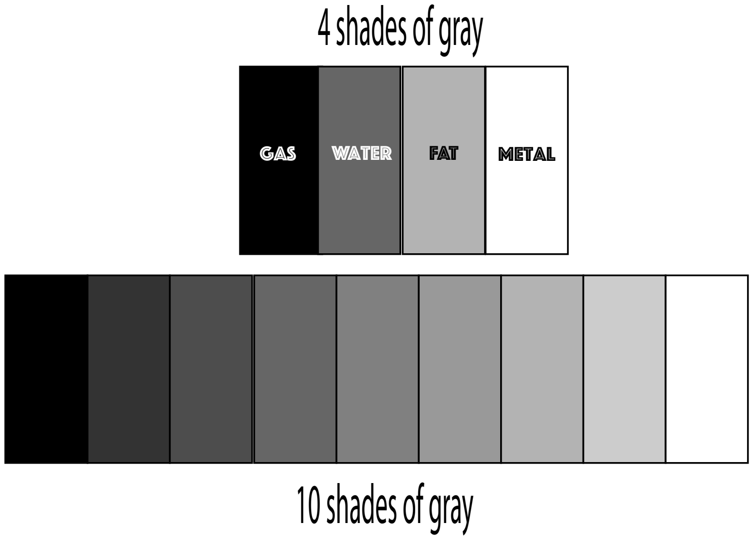

Tome 5
BOURGERY

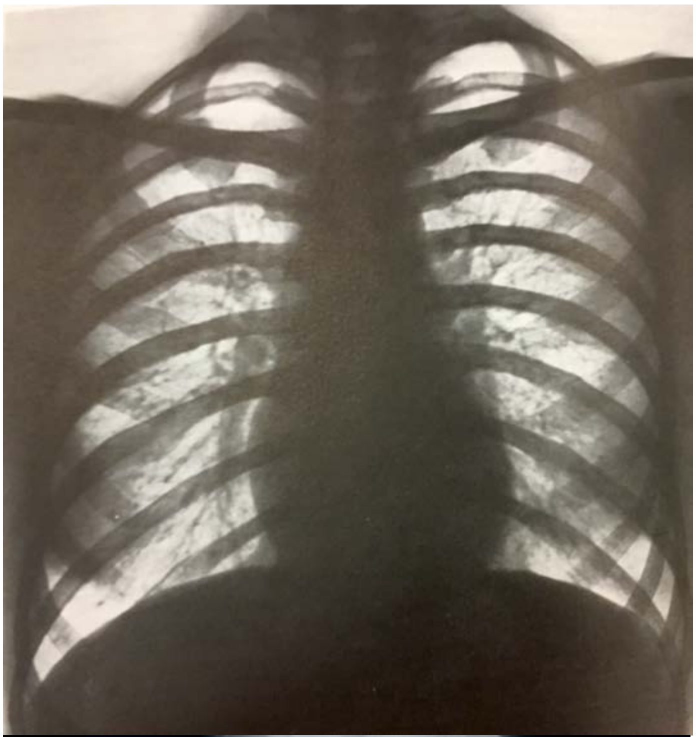

BOURGERY

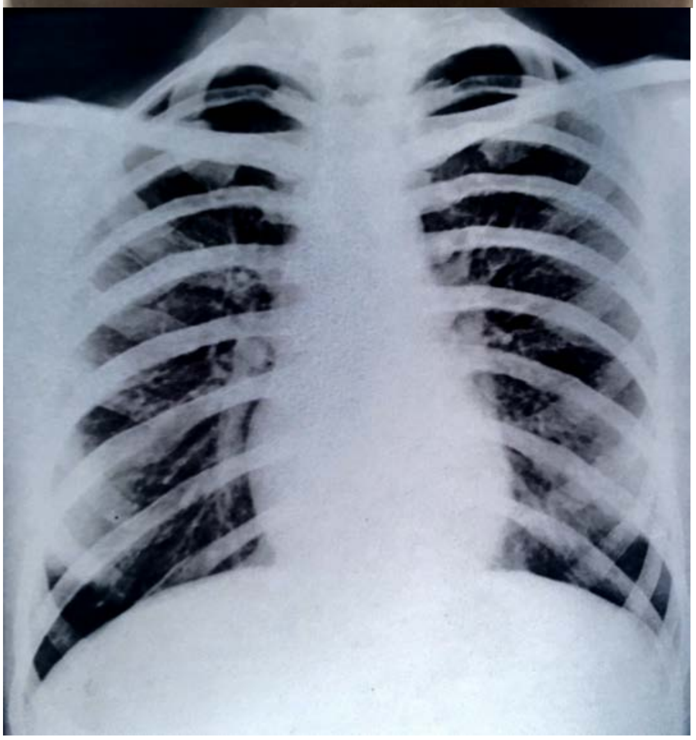

J.M. Bourgery & N.H. Jacob
ATLAS
OF HUMAN ANATOMY
AND SURGERY
THE
COMPLETE
PLATES
Atlas d'anatomie humaine et de chirurgie
Atlas der menschlichen Anatomie und der Chirurgie
TASCHEN
Bibliotheca Universalis

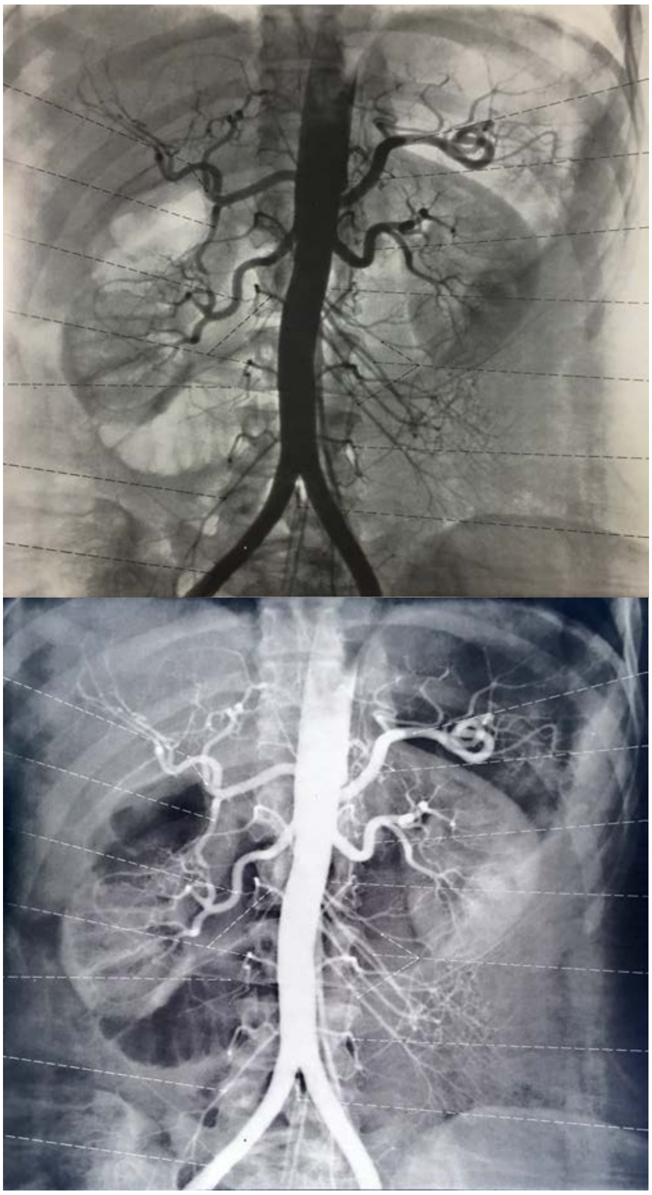


As a scientific discipline, the medical radiology was born immediately when, in September 8th, 1895, Wilhelm Conrad Roentgen who was a good photographer discovered the X-rays; he took the first picture of his wife's head on a photographic film he developed in four positive shades of gray from black to white: 1) metals like gold and calcium are featured in black (opaque); 2) hydric organs like viscera and muscles are in dark grey; 3) fatty structures are in light gray; 4) gaseous structures are in white (transparent) (Fig). Many years later the radiologists have become used to examine their radiographs inspected on dedicated view boxes on the same but negative shades of gray from the white (opacity) to the black (transparency): the metals are featured in white, the gas is featured in black, the fat is in dark gray, the viscera are in light gray. The contrast of the radiograph varies upon the intensity of the X-ray beam and the sensitivity of the film like in photography using the sunlight. In order to increase the performances of the radiodiagnosis, several contrast media have been introduced to enhance either the gaseous contrast by injection of air or CO_2 (transparency), or the metallic contrast by barium sulfate for the digestive tract or iodinated molecules for the blood and the cavities (opacity). The human eyes cannot discriminate more than sixteen shades of gray. Using high resolution matrices (up to 2048x2048 pixels) the images obtained for digital angiography, CT scanning (at the beginning termed tomodensitometry), but also magnetic resonance imaging (MRI) and conventional ultrasonography in real time are treated by informatics methods either in positive or negative visions of the scanned volumes of the body; the four fundamental shades of gray are subdivided in multiple shades of gray studied by densitometry; for instance, on CT scanner, an hydric structure containing iron such as a vascularized tumor may have a spontaneous density of 75, a number that inflates when a bolus of iodinated compound is injected. Even though MR and ultrasonographic imagings are visualized with the same scales of gray than CT scan and digital angio, their respective effects result from totally different physical fundamentals than the X-rays.

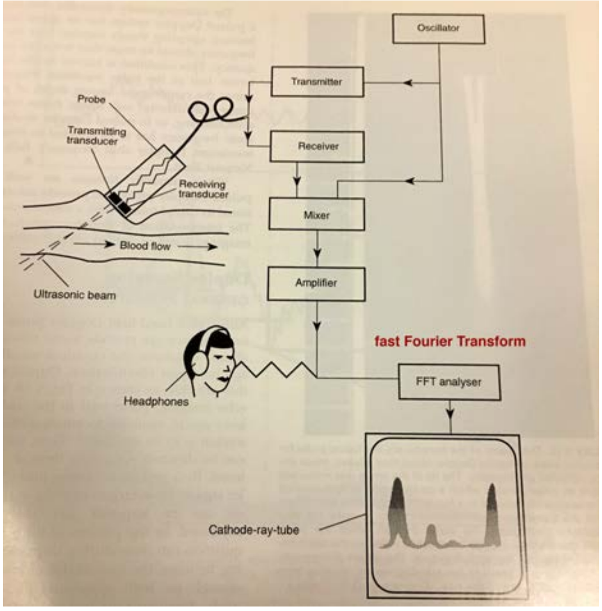


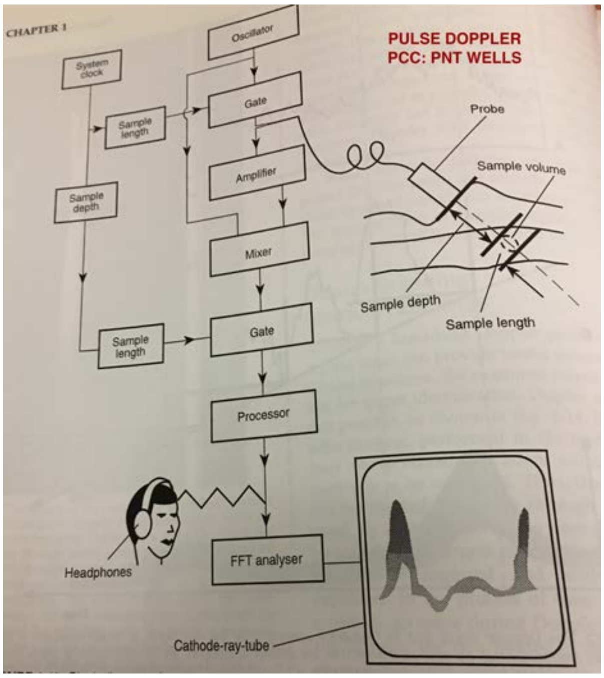




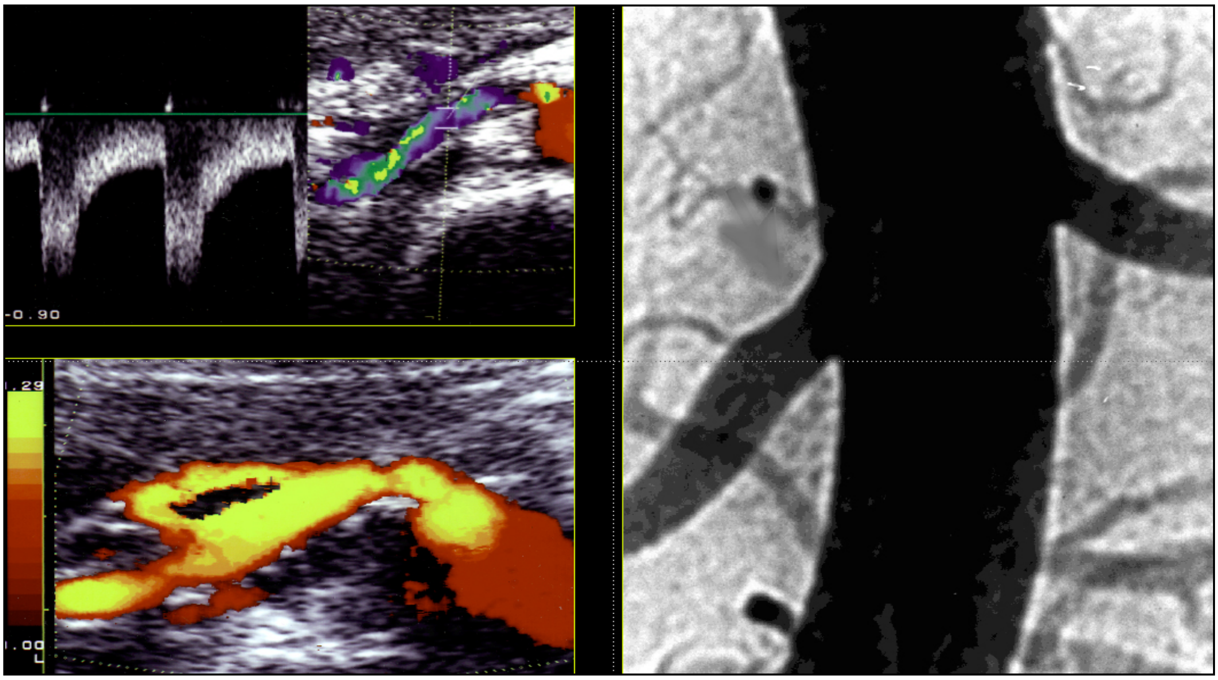


The use of colored digital medical images provided by cross-sectional tomography (CT scan and MR) relies on aesthetic or educational purposes: they do not reflect scientific physiological images with the exception of color doppler. The latter explores the hemodynamics all along the cardiovascular axes (Fig). The simple doppler provides a curve and a special noise according to the sense of the blood flow and the axis of the ultrasonic probe. Pulse doppler quantifies the phenomenon mainly with the measurement of the resistive index of Pourcelot. Léandre Pourcelot[xiii] (born in 1940) is a physician and a doctor of sciences in acoustics who, in 1965, introduced vascular doppler in Europe[xiv]. He had become famous when he participated in the cardiovascular follow-up of the cosmonauts and the astronauts traveling in the space via satellites[xv]. Mostly under the influence of the Japanese industry the pulsed doppler has become colored by encoding using the RGB scale of Newton more often than the CMYB scale of Engelmann. When the axes of the ultrasonic beam and the blood flow go in the same direction, the conventional encoding is in red color; conversely, when they cross each other the conventional encoding is in blue (Fig). According to the operator's hand manipulating the probe, an arterial blood flow is colored in red or in blue; similarly, the venous blood flow may be colored in red. Such a duplicity often introduces misinterpretation of the vascular tree examined just on the picture by third persons. On the other hand, color doppler gives data on the speed of the blood flow. The faster the flow the yellower the light. For instance, in a case of stenosis of the trunk of a renal artery by a plaque of atheroma, one can see the red color of the aortic lumen and of the prestenotic part of the trunk and the brightly yellow part of the stenotic area because there is an acceleration of the blood flow (Fig).





Color doppler is useful in the field of the tumor syndrome. The latter may be hyperechoic, isoechoic, hypoechoic or anechoic according to the ratio between solid components (benign or malignant tumors) and liquid components (cysts or pseudocystic tumors, necrotic components) whether they are heterogeneous or not. Most of the time the benign cysts are anechoic with a posterior enhancement of the echoes. A dependent level of echogenic fluid can be observed in the abscesses. Necrotic malignant tumors may mimick benign cysts save they are surrounded by a thick and irregular vascularized wall. Color doppler is useful in order to demonstrate the presence of vascular echoes in the transparent mass in fact rich in anarchic vessels. However, it may happen a transparent mass looks like a cyst without signs of vascularity even if the intensity of the ultrasonic beam is increased because the intravascular flow is very slow almost immobile. In such a case one takes advantage of the intravenous injection of contrast media made of gaseous microbubbles. We could demonstrate the actuality of blood vessels in a case of multiple pseudocystic aneurysms of a kidney magnified by intratumor echoes produced by the microbubbles.



Another kind of pitfall may be induced by a defective scanning of the vessel. In such a case the sonographer creates a cloud of multiple colored spots trespassing the area of the vessel itself toward the surrounding soft tissues. Such a pitfall must be differentiated from the artifacts induced by an hyperpulsatile vessel shaking the space every systole.

In conclusion,

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