LOUIS BOLK INSTITUTE

Physiology

Organphysiology from a Phenomenological Point of View

Christina van Tellingen MD

BOLK'S COMPANIONS FOR THE STUDT OF MEDICINE

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FOR THE STUDY OF MEDICINE

About the Author

Christina van Tellingen MD (1949) has been a general practitioner since 1982. She has educated medical students, physicians, and therapists in the United States, Canada, and Europe. She teaches medical students and physicians at the University of Witten/Herdecke, Germany. She is a member of the Medical Section of the School of Spiritual Science at the Goetheanum, Dornach, Switzerland.

About the Project

The project *Renewal of Medical Education* aims to produce Companions that demonstrate how the insights of current biomedical science can be broadened by using the Goethean phenomenological method. This method innovates current concepts and expands the understanding of biochemical, physiological, psychological, and morphological factors in living organisms and their development in time and space, and in health, illness, and therapy. The project is commissioned by the Kingfisher Foundation, which aspires the development, application, and publication of the Goethean phenomenological research method in the widest sense, to complement and innovate the accepted scientific view and research method.

BOLK'S COMPANIONS FOR THE STUDY OF MEDICINE complement current medical education, specifically disclosing human qualities in the fundamental biomedical sciences of today.

BOLK'S COMPANIONS FOR THE PRACTICE OF MEDICINE contribute to a scientific phenomenological basis for integrative medicine and integral psychiatry.

3. The Liver and Digestive Tract

3.1. Introduction

The intake of nutrients into the organism takes place in the digestive tract. Food is broken down in the intestines, becomes water-soluble, and is taken up into the bloodstream. The venous circulation from the intestines (the portal circulation) subsequently takes most of the nutrients to the liver, where they undergo further conversions, and finally enter the venous bloodstream of the liver to be transported to their final destinations.

We will consider the physiological morphology and embryology, blood supply, physiology, regulation, and function, of the liver and digestive tract to gain a view of their characteristic place in the organism.

3.2. Physiological Morphology

3.2.1. Shape of the Liver and Digestive Tract

Intestines

The intestines have a tube-like shape, like the lower respiratory tract as described in section 2.2.1. The lower respiratory tract and the intestines both originate from the primitive gut, but the intestines are not fixed in cartilage or being passively moved like the airways. The intestines are in constant, slow movement, which is mostly active and autonomous, again unlike the movement of the respiratory tract (section 2.4.2.). The shape and position of the different parts of the intestines in the abdominal cavity is dependent on outside influences, such as the tone of the abdominal muscles and the diaphragm, the shape of the spine, the filling of the large abdominal vessels. Surgeons may reposition the intestines after surgery more or less at random. How much this affects the function of the intestines is unknown.

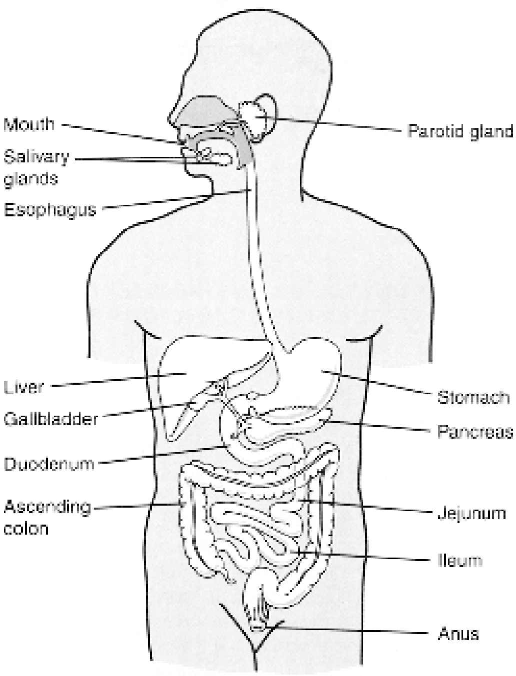

Fig. 3.1. The liver and intestines (from Guyton 2000)

The intestines are connected through and surrounded by peritoneum, which also carries the blood vessels and autonomic nerves.

Liver

The external form of the liver is determined by its surrounding structures. The liver is a large organ, which has impressions of the right kidney, gallbladder, and vessels on its lower surface. The diaphragm determines the shape of its upper surface. The liver is situated on the right side of the abdominal cavity.

The liver is a large, expandable organ that contains more than 10% of the total volume of blood at any moment. It is one of the largest organs of the body, contributing just short of 2.5% of the total body weight, about the same amount as the brain.

➔ *The external shape of the liver and intestines is like the surface of a body of water: everything around it makes an impression on it and the environment determines its form.*

3.2.2. Structure of Liver and Intestines

The Intestines

The intestines have a membrane-like quality with an inner layer of mucosa through which the nutrients enter the organism via the blood vessels just underneath the mucosal surface. Several layers of smooth muscle cells surround the mucosa of the intestines. In the walls of the intestines lies a plexus of the autonomic nervous system with both sympathetic and parasympathetic fibers, the intramural plexus (fig. 3.7.).

The intestines, like the lower respiratory tract, have special mucosa-associated lymphoid tissue (MALT), which deals with incoming pathogens, since, like the respiratory tract, they interface directly and intensively with the surroundings.

The Liver

The liver is a parenchymatous organ. The main type of functional cell is the hepatocyte. Hepatocytes all appear similar to one another. They make the liver parenchyma look homogenous, and are structured into lobes and lobules. The liver lobule is hexagonal in shape.

The structure of the liver lobule allows a constant, slow stream of blood (both venous and arterial) to pass by each hepatocyte directly. The incoming blood flows from the periphery of the liver lobule into large sinusoids, and slowly moves toward a central venule (fig. 3.4.).

The sinusoids of the hepatic lobule are lined by hepatocytes, endothelial cells, and Kupffer cells. Kupffer cells are cells from the reticuloendothelial system that act as phagocytic macrophages. They are instrumental in removing from the portal blood, among others, a detectable number of coli bacilli from the intestines. A culture of systemic blood does not normally grow any bacteria. The interface of the liver with the outside world becomes visible in such a phenomenon!

Between the hepatocytes originate the bile canaliculi. They lead the bile that is secreted by the hepatocytes to the common bile duct, via the terminal bile ducts and hepatic bile duct. From there the bile either flows directly into the duodenum or is stored in the gallbladder.

The liver parenchyma has a high threshold to pain. Cells in the liver and digestive tract have a strong regenerative capacity.

➔ *The intestines have a membrane-like structure that is more muscular than the respiratory tract and exhibits autonomous motility. The liver is a parenchymatous organ that consists mainly of one type of cell, the hepatocyte.*

3.2.3. Embryology of Liver and Intestines

The intestines develop from the primitive gut. The primitive gut forms in the 4th week after fertilization, when the embryo goes through its lateral folding. Lateral folding results in the formation of the ventral wall of the embryo. Through cranio-caudal growth, a tube is formed which runs through the embryo from top to bottom: the primitive gut, which is lined by parts of the yolk sac (fig. 3.2.). At its cranial end, the lung buds off from the

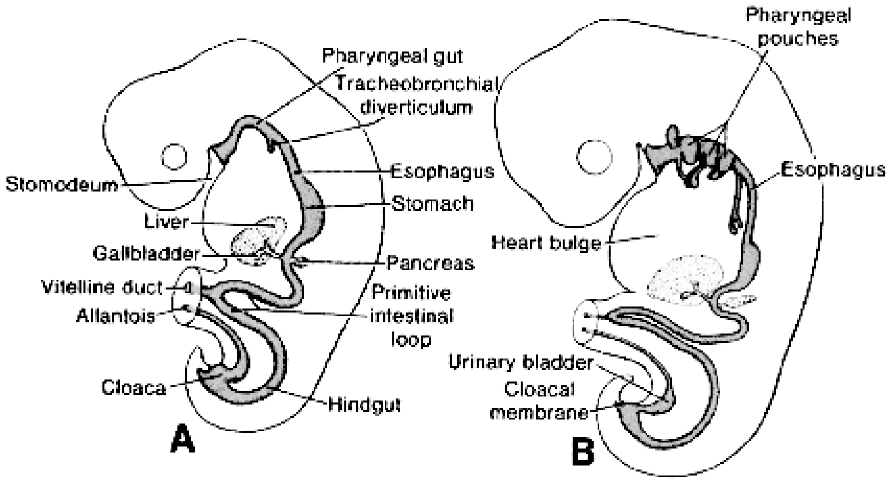

Fig. 3.2. The gastrointestinal tract and liver in the 4th (A) and 5th (B) week of embryological development (from Sadler 1995)

primitive gut; about midway, the liver bud develops into a parenchymatous organ.
During the second trimester of pregnancy, the liver is the main organ for the synthesis of red blood cells. There is also some red cell production in the spleen and lymph nodes at that time. During the first trimester, red blood cells are formed in the yolk sac. During the third trimester, red blood cell development is taken up by the bone marrow. During embryological development, the liver is relatively much larger as compared to the total size of the body.

➔ *The primitive gut gives rise to the lower respiratory tract as well as the intestines and the liver. The latter becomes a parenchymatous organ.*

3.3. Blood Supply to Liver and Intestines

The liver has an ample blood supply. Around one quarter of the cardiac output (27%) is directed toward the liver. This means that 1350 ml of blood flows through the liver each minute. Three quarters of the blood flow through the liver is venous blood that comes from the portal vein, one quarter is arterial blood from the hepatic artery. The two types of blood flow into the liver sinusoids and mix there. Consequently most of the blood flowing through the liver is venous blood, which is low in oxygen saturation.

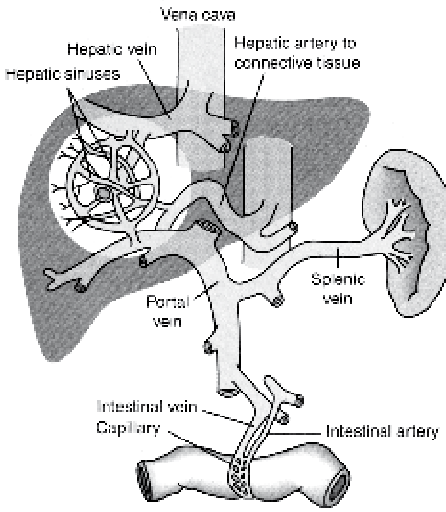

Fig. 3.3. Blood supply to the liver and intestinal tract (from Guyton 2000)

The Intestinal Blood Supply and the Portal Vein

Blood in the portal vein comes from the intestines, spleen, and pancreas (fig. 3.3.).

It carries with it broken-down mostly non-fat nutrients (chiefly carbohydrates and proteins). These have been rendered water-soluble in the intestines and are absorbed into the blood. The countercurrent exchange system between the intestinal arteries and veins allows the portal vein to carry extra oxygen that comes directly from the intestinal arterioles, especially at low flow rates. The *specialized venous blood supply* of the liver through the portal system is unique in the body. There is only one other place where this occurs, namely in the pituitary gland.

The Hepatic Artery

The hepatic artery carries blood that is fully saturated with oxygen from the aorta to the liver. About three-quarters of the oxygen the liver uses comes from the hepatic artery. The liver maintains a nearly constant oxygen consumption level.

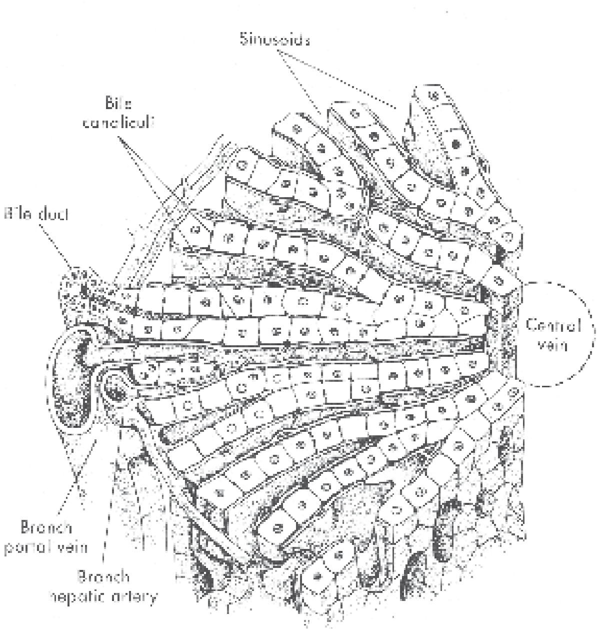

Fig. 3.4. Blood flow in the liver (from Berne 1998)

Blood Flow in the Liver

The two blood streams that flow into the liver empty into the large sinusoids in the liver lobules (fig. 3.4.). They form a thin layer of blood around the hepatocytes. The portal system blood supply and that from the arterial hepatic system vary reciprocally, so that the blood flow to the liver cells is near constant. Only the blood flow in the hepatic artery can be auto-regulated to achieve this.

Under the low pressure-gradient between the sinusoids and the liver veins (the vascular resistance in the liver bed is very low), the nutrients are taken up into the hepatocytes. There are large pores or fenestrae in the sinusoids, which allow the formation of lymph in the liver in the spaces of Disse. Half of all lymph arises in the liver.

The liver is a large, expandable venous organ and acts as a blood reservoir. In bleeding or in shock, when there is a shortage of intravascular fluid, the liver can expel several hundred milliliters of blood, which it keeps stored. The liver contains 10-15 % of the total blood volume at any one time. The spleen is also a blood reservoir; it can store up to 100 cc of blood at a time. The large abdominal veins may store another 300 cc. Thus the intestinal system may store 650 cc of blood or more. By comparison, the heart and lung only store 75 and 150 cc respectively.

➔ *The liver has the greatest perfusion of blood of all the organs in the body. Its blood supply consists for three-quarters of blood that has low oxygen saturation, which flows to the liver in a specialized venous system (the portal circulation), and one quarter of blood that has high oxygen saturation. The liver capillaries form a thin layer of blood in the sinusoids. The intestines have a specialized countercurrent exchange system. The intestinal organs act as a blood reservoir.*

3.4. Physiology of the Liver and Intestines

3.4.1. Physiology of the Intestines

The different parts of the intestines are specialized in different physiological processes related to digestion, such as moving the food stream along (esophagus), absorption of nutrients in addition to moving the food stream along (small intestines), or excretion in addition to moving the food stream along and absorption (large intestines).

Movement in the intestines is initiated by stretch. The smooth muscle layers of the intestine form a functional syncytium that contracts rhythmically, and normally moves the food in peristaltic waves from mouth to anus. Stretch makes the unitary smooth muscle cells more excitable, so that superimposed action potentials are generated on top of continuous, spontaneous slow waves. Action potentials are based on the influx of calcium ions, along with some sodium ions, into the cell. They accompany the contraction of the smooth muscle layers (see also section 5.4.2.).

The mucous membrane of the small intestines allows for *passive diffusion* and *active absorption* of nutrients into the blood stream, as well as possibly allowing a *passive* solvent drag (solvents carrying dissolved substances along).

- *Carbohydrate* components like glucose and galactose are absorbed *actively* with the help of Na^+/K^+ ATPase.
- *Protein* constituents are mainly absorbed *actively* by means of a variety of carrier systems, depending on the types of amino acids; mostly this is also a sodium co-transport mechanism. Some amount of whole protein uptake also normally takes place, especially in infancy. When whole protein absorption is increased in adults, it relates to the development of food allergies (Linder 1997).
- *Lipids* are absorbed by *passive* diffusion through the mutual cell membrane since they are soluble in the cell membrane. Lipids are transported in the intestine and disposed of locally by the micelles. Most lipids enter the lymph stream of the thoracic duct in the form of chylomicrons via the endoplasmic reticulum of the mucosal cells. They are deposited into the blood stream where the thoracic and lymphatic ducts empty into the subclavian veins. Some lipids are absorbed directly into the portal blood.

The intestines also play an *active* role in the secretion of myriad local digestive enzymes and hormones that influence the motility of the digestive tract and prepare the foodstuffs for absorption into the body by breaking them down and making them water-soluble. Some important enzymes are pepsin, trypsin, lipase, and amylase. Some important local hormones are gastrin, cholecystokinin, and secretin.

The intestinal tract allows for the nutrients to be taken up into the organism from outside through its membrane-like mucosal structure. It actively moves the food along in peristaltic waves of contraction of its muscular layers, and excretes waste products. Absorption of the *nutrients across the intestinal mucosa is both active and passive. The intestinal tract actively secretes enzymes and hormones for the digestion of nutrients and to increase the motility of relevant parts of the intestinal tract.*

3.4.2. Physiology of the Liver

The hepatocytes are a large pool of chemically reactant cells. They have a high rate of metabolism and effect a large number of chemical conversions of the nutrient compounds. The chemical conversions render many compounds more water-soluble and give them the form that is most usable for the body at the time. This may be either a storage form or as an active metabolite. They temporarily absorb and store one half to three-quarters of all absorbed water-soluble nutrients.

Carbohydrates

Much of the metabolic activity of the liver is directed towards carbohydrate (glycogen) storage and reactions like glycogenolysis and gluconeogenesis. The liver has a glucose buffer function for the serum of the blood. It plays an important role in glucose homeostasis since it can convert glucose to glycogen, lipids, or amino acids, as well as vice versa except the direct conversion of lipids to carbohydrates (fig. 3.5.).

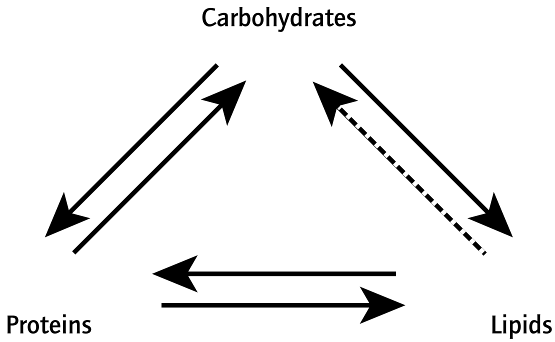

Fig. 3.5. The liver converts carbohydrates to proteins or lipids and vice versa.

Proteins and Amino Acids

Amino acids from the diet are not stored as free amino acids, but as rapidly exchangeable proteins, specifically in the liver. The free amino acid levels of the blood are replenished by the degradation of proteins in the liver. The liver plays a central role in homeostasis by regulating amino acid metabolism.

The liver cells form all plasma proteins, including albumin. One third of the amino acid required in the diet can be accounted for by the synthesis of albumin and other plasma proteins in the liver. Albumin may be a temporary amino acid store and act as a vehicle for transporting amino acids to peripheral tissues to replace daily losses (Linder 1996). The processes of transamination and deamination allow the liver to convert amino acids into other amino acids, glucose, or lipids (fig. 3.5.). Deamination leads to NH_4^+ formation, which is converted to urea for excretion in the kidneys. Essentially, all urea in the body is formed in the liver. Decreased liver function results in high ammonia levels, which impairs consciousness.

The liver is the site where the hemoglobin of the blood is broken down to bilirubin and excreted in the bile.

Lipids

The liver is the site of several specific reactions in lipid metabolism. The liver can synthesize lipids from proteins or carbohydrates. The liver synthesizes phospholipid, cholesterol, and many lipoproteins. Around 80% of synthesized cholesterol is converted by the liver into the more water-soluble bile salts. At the same time, this is the major route of excretion for cholesterol. Thus the liver plays a central role in regulating the serum cholesterol level.

Through ß-oxidation of fatty acids, the liver can supply the organism with energy in the form of ketone bodies. The liver is essential in maintaining lipid homeostasis through its central role in lipid synthesis and catabolism (fig. 3.5.). (For further information on the biochemistry of carbohydrates, proteins, and lipids see also the *Biochemistry Module* of **BOLK**'S COMPANIONS FOR THE STUDY OF MEDICINE)

Bile

The hepatocytes excrete bile. Bile salts account for about half of the solutes in bile. They are the degradation product of cholesterol, and can help both to emulsify the lipids in the gastrointestinal tract as well as aid in their absorption through the formation of micelles. Through the bile, the liver can also directly excrete excess cholesterol as well as bilirubin, the metabolite of hemoglobin. Other constituents of the bile include lecithin and electrolytes. The gallbladder mainly stores and concentrates the bile. Part of the bile, including cholesterol, is resorbed from the gastrointestinal tract into the portal circulation and thus enters the *enterohepatic cycle* (fig. 3.6.).

Other Physiological Activity of the Liver

The hepatocytes also play a role in storing iron and some vitamins (A, D, B_{12}), excreting calcium through the bile, as well as inactivation, degradation, and excretion of drugs, toxins and hormones.

The liver is characteristically active in physiological processes in metabolic cycles. It plays a role in storage and in maintaining homeostasis.

➔ *The physiology of liver and intestines consists of many active processes.*

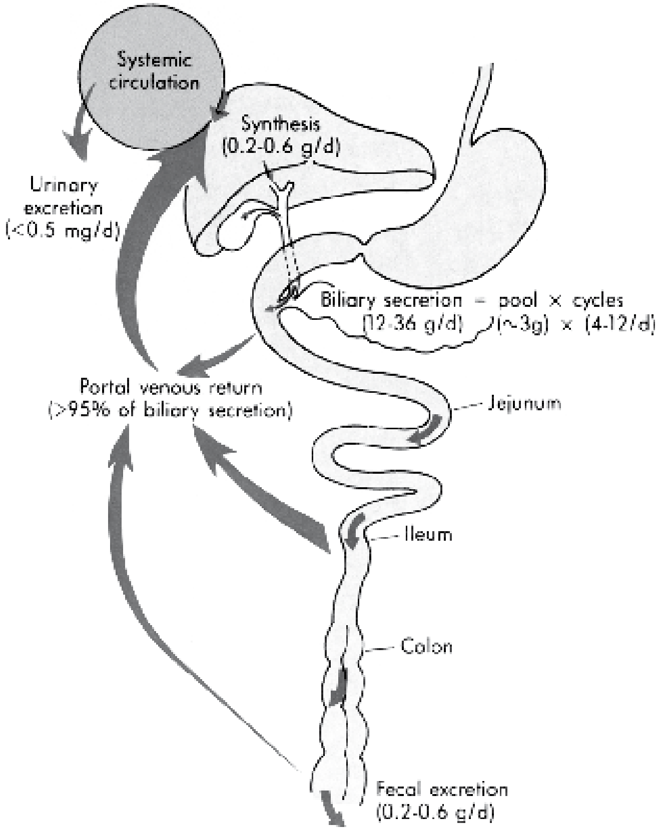

Fig. 3.6. The enterohepatic circulation of bile acids (from Berne 1998)

3.5. Regulation in Liver and Intestines

3.5.1. Intestines

Hormones

Autonomous intestinal functions are regulated locally by the secretions of hormonal substances from the glands in the mucosa through mechanical pressure of the food that enters a particular part of the intestines. Intestinal organs such as the pancreas add digestive hormones such as secretin and cholecystokinin, which stimulate the secretion of bile into the duodenum. Three hormones from the pancreas, glucagon, insulin, and somatostatin, are important in regulating the metabolic functions in the liver. The internal secretion of the pancreas of insulin and glucagon regulates the metabolism of, especially but not exclusively, the carbohydrates in the whole organism. Intestinal hormonal substances are all peptides or derivatives of peptides.

Autonomic Nervous System

Autonomic stimulation and inhibition play an important role in intestinal function. The autonomic nervous system of a particular segment is stimulated by direct contact with the food. The intramural plexus (fig. 3.7.) consists of two systems of plexuses, which both have sympathetic as well as parasympathetic innervation: the *myenteric* plexus mainly regulates movement, the *submucosal* plexus mainly regulates the secretions. The neurons of these plexuses con-

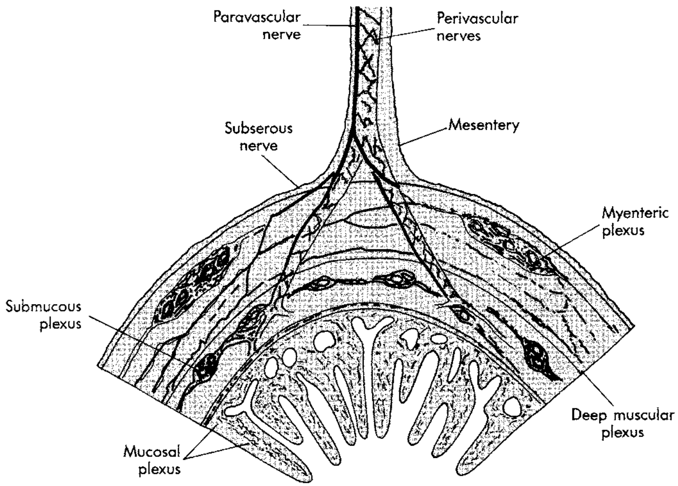

Fig. 3.7. Autonomic innervation of the intestines. (from Berne 1998)

tain many of the neuropeptides (gut-brain peptides) that are found in the central nervous system.

- Parasympathetic stimulation:
  Parasympathetic stimulation mostly stimulates peristalsis, relaxes the sphincters, and stimulates the secretions. Without parasympathetic stimulation, the movement of the intestines becomes very slow. Parasympathetic stimulation can be enhanced by brainstem activity in the *cephalic phase* of regulation at the sight or thought of food. Brainstem activity in the central nervous system is transmitted to the gastrointestinal tract through the vagus nerves. The cephalic phase stimulates salivation and the secretion of gastric and pancreatic juices.
- Sympathetic stimulation:
  Sympathetic stimulation mostly slows the propulsion of food, tightens the sphincters, and inhibits the secretions.

3.5.2. Liver

Mainly local hormones from the gastrointestinal tract such as insulin, glucagon, and somatostatin regulate liver activity. The liver secretes *angiotensinogen*, which can be converted by renin from the kidneys into angiotensin I (see also section 4.5.), which in turn is converted in the lung endothelium to angiotensin II (section 2.4.4.). Angiotensin II is an important regulator of blood pressure.

➔ *Regulation in the liver and intestines is mainly local. The local autonomic nervous system plays an important role as well as local hormonal substances. Some intestinal hormones have a general metabolic function. There is also a cephalic regulatory phase in the stimulation of the vagus nerves by the sight or thought of food.*

3.6. Function of the Liver and Intestines in the Organism

The function of the liver and intestines is to *supply* the organism with nutrients. The physiological processes that underlie this function are active processes, but the function of supplying is itself mainly passive. The intestines facilitate the intake of nutrients and the excretion of fecal matter. The liver *maintains* homeostasis in the metabolic functions of the organism. It *stores* mainly glycogen itself. Also maintaining and storing are basically passive functions (an active process is, for instance, regulating). Liver and intestines also contribute to homeostasis by pooling a significant amount of blood, which can help *maintain* the extracellular volume.

➔ *The function of liver and intestines in the organism is to supply, maintain, and store. These are mainly passive functions.*

3.7. Conclusion

- Morphology:
  In its overall shape, the liver is a large organ that is *passively* formed by its surroundings, like the lungs. The intestines are membrane-like in structure, like the lungs, but are not rigid and exhibit *active* autonomous movements. The liver structure is that of uniform, homogenous parenchyma.
- Blood supply:
  The blood supply of the liver is *the largest* in the body. It has low oxygen saturation like in the lungs, but has mixed arterial and venous blood through the presence of the specialized and *unique venous portal system*. Both lung and liver have a large capillary net that forms a thin layer of blood. The pressure gradient that moves the blood in the capillaries is even lower in the liver than it is in the lungs.
- Physiology:
  The liver and intestines are *active* physiologically, contrary to the lungs, even though all three come from the same embryological tissue (the primitive gut). The liver and intestines transform metabolites to render them suitable for use by the body.

	Lung +	Liver + Respiratory Tract	Kidneys Intestinal	Heart Tract
Morphology	Shape from without, tubular organ, **membranous structure**	Mostly shaped from without, uniform parenchyme, tubular organs		
Blood supply	50% of *weight* is blood, largely O_2 unsaturated, capillary blood in thin film	Largest *flow*, special *venous portal system*, 1⁄4 is O_2 saturated, 3⁄4 has a low O_2 saturation, capillary blood in thin layer		
Physiology	Passive diffusion	**Great activity in metabolic cycles**		
Regulation	Mainly from without, via the central nervous system	Both through local hormones and local autonomic plexuses, some via central nervous system		
Function	Passively supplying	Passively supplying, maintaining, and storing		
Characteristic	Membrane-like tubular structure, *diffusion of gases* (O_2 and CO_2) and water	Physiologically active in metabolic cycles, diffusion and *absorption of fluid nutrients* in tubular part		

- Regulation:
  The liver and gastrointestinal tract are mainly regulated autonomously. Regulation is mostly local, by local hormones and the local autonomic nervous system.
- Function:
  The function of liver and intestines is mostly *passive*, since their function is to supply the organism with the compounds needed in metabolism, store them, and aid in maintaining homeostasis.

➔ *Characteristic for the liver and intestines is that they are active physiologically. The hepatocytes are active in the cycles of metabolism. In structure, blood supply, and function liver and intestines are passive, similar to the lungs. The tubular, membranous structure of the lungs and respiratory tract manifests again as the tubular structure of the intestines, where diffusion and active absorption takes place of fluid nutrients, rather than gases. The parenchymatous nature of the liver is not found in the respiratory tract.*

Physiology

Organphysiology from a Phenomenological Point of View

Can physiology give more insight into the living human organism than the mere facts reveal at first? Is the level of activity the same for all organs? Are the vital qualities at work in organs unique for organisms and limited to biological activity? Can we find a scientific basis to research the coherence between organ systems?

By enhancing the current scientific method with phenomenological points of view we can find meaning in the facts and understand them as an expression of life itself. The phenomenological method makes the relation between organs visible and comprehensible. It approaches scientific facts from the point of view of their coherence and can give totally new insights this way.

What emerges is a grasp of the interrelations between biological processes, consciousness, and nature.

the natural source of knowledge