A SUMMARY OF OUR STUDIES CONCERNING THE STRUCTURE AND FUNCTION OF BLOOD CAPILLARIES

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HISTORICAL NOTE

Galen was of the opinion, based upon his macroscopic observations, that the vessels at the end of the arterial tree, have a diameter no greater than that of human hair. Harvey (1628), centuries later, using a hand magnifier, gained the impression that there are "holes through the flesh" which, he assumed, represent channels of communication between the arterial and venous system. Malpighi (1661), who investigated frog's lung with the microscope, was probably the first to demonstrate the existence of capillary vessels. Later on, Hall (1831) with his anatomical approach was able to show the difference between the arteries and capillaries.

Rouget's work, toward the end of the last century (1873), called attention to certain contractile elements that he has seen in the capillary walls of the tadpole's tail. All these observations concerning the nature of blood capillaries were ably summarized and reviewed by Krogh in his book "The Anatomy and Physiology of Capillaries" published in 1930. This paper is a summary of our experiments (References II) which I and my research collaborators made on the Invertebrata, Amphibia and mammals since 1932.

STRUCTURE

The blood capillaries are the microscopic channels which establish connection between the arterial and venous system. The capillary wall is made up of one or two layers.

Nomenclature As a rule, the capillaries are divided into five segments: arterial capillary, distributing capillary, net capillary, collecting capillary and venous capillary. In addition to these, there are the bifurcations of the arterial capillary and communicating branches.

Lining Cells The lining of the blood capillary wall consists of endothelial cells. The so-called contractile cell may or may not be present. The ratio between endothelial and contractile cells varies considerably in all five segments, and even to a greater extent in different organs. The density of contractile cells is greatest in the arterial capillary wall and it decreases rapidly toward the net capillary and again increases gradually toward the venous capillary. Furthermore, the contractile cells are present in groups at the bifurcation of the arterial capillaries. The number of these contractile cells is greater above the bifurcation than at the lower end.

The width of spaces separating individual endothelial cells varies greatly in the different segments. As one follows the course of the arterial capillary toward the venous capillary, these spaces become gradually greater. And when the capillary lumen dilates the intercellular spaces further enlarge.

Diameter Diameter of the blood capillaries, as a rule, is the smallest in the net capillary and larger toward both the arterial and venous ends. In the sinusoides, the diameter of the net capillary is larger than in either the arterial or venons capillary.

Distribution The distribution of the blood capillaries are found to be varying considerably in different organs. One may classify the distribution of blood capillaries as follows: 1) net type, 2) folded net type, 3) elevated type, 4) basket type, 5) sinusoid type, and 6) sinus type.

Vasomotor Innervation It is reasonable to assume that the vasomotor fibres innervate the blood capillaries.

CONTRACTILITY

The blood capillaries are so constituted as to be able to contract passively and actively.

Passive Contractility The passive type of contractility is a change in the diameter of the capillaries caused by the expansibility of the wall. The arterial capillary has the greatest capacity for passive expansion. The change of the expansibility of the wall is brought about by various chemical substances.

Active Contractility The active contraction of the capillaries is defined as the contraction of the capillary wall which can be elicited by physiological means. It appears that the contractile cells are responsible for active contractility. In addition to the vasomotor innervation, the active contractions are governed by hormonal and chemical influences, as well as by the blood pressure changes. It differs greatly in degree in various segments of the capillaries, being the greatest in the arterial capillary and the least or none in the net capillaries. The degree of active contractility of the capillaries is in direct proportion to the number of contractile cells within the wall. A strong active contractility exists at the bifurcation of the arterial capillaries where contractile cells are found in large groups.

Tonus Capillaries have an active and a passive tonus. The former is due to a continuous contraction of the contractile cells, and the latter is produced by the aggregate tension of the wall.

Rhythmical Contractions The blood capillaries, especially arterial capillaries, change their diameter rhythmically through the active contraction of the contractile cells. There is also a passive contraction which is induced by rhythmical blood pressure changes in the arteries.

Vasomotor Action The vaso-constrictors increase the active tonus of the capillaries while the vaso-dilators decrease the active tonus by the release of neuro-effectors from the nerve endings. The constrictor substance is almost identical with adrenalin, the dilator substance with acetylcholine.

Reflexes There are four separate reflex arcs through which the mechanism of the capillaries may be influenced. They link up as follows: 1) within the same capillary system, 2) connecting two or more adjacent capillary systems, 3) heart, artery, vein to capillaries, and 4) organs to capillaries.

Mechanism of Contractions The wall of the capillaries consist of four elements: nerve endings, contractile cells, endothelial cells and intercellular cement substance. The nerve endings release neuro-effectors; the contractile cells produce an active contractility; the aggregate of all four components represents the passive contractile force. Neuro-effector released from vaso-constrictor, adrenalin, pituitrin and certain ions produce contraction by their effect upon the contractile cells. Neuro-effector released from vaso-dilator, histamine, or acetylcholine decrease the active tonus by antagonizing the neuro-effector released from vaso-constrictor or adrenalin. Dilute solution of adrenalin, pituitrin, lactic acid, etc. increase expansibility by acting on the wall of capillaries.

PERMEABILITY

Site of Penetration The permeability of the blood capillaries is quite different in the various segments. Particles and leukocytes penetrate easily through the net and collecting capillaries, especially near the transitional points.

Path of Penetration The main avenue of penetration through the capillary walls may be through the intercellular cement substance between endothelial cells.

Factors Influencing Penetration Penetration of substances through the capillary wall is influenced by the permeability. The permeability is changed by the contraction or dilatation of the wall in either the active or passive, or by the physico-chemical changes of the wall. On the other hand, the penetration of fluid and particles through the wall is influenced by physical and chemical differences of the fluids in the intra- and extravascular compartments, i. e. hydrostatic pressure, effective osmosis, diffusion tension, partial pressure, electric charge, etc.

Diapedesis of Leukocytes The white blood corpuscles migrate mainly through the walls of net and collecting capillaries. The velocity of migration differs widely in the individual cases.

BLOOD FLOW IN THE CAPILLARIES

In the resting state, when blood volume and pressure decreases, the contraction or dilatation at the bifurcations of the arterial capillaries does control the flow. The direction of the flow in the net capillaries is sometimes changed by the communicating branches. In this way, the blood flow is controlled uniformly throughout the entire capillary bed.

In the active state, in which blood volume and pressure increases, all capillaries dilate uniformly. In this case the blood current is fast and the direction of the flow in the net capillaries remains constant.

When the blood pressure rises, or the venous side is suddenly obstructed the arterial capillary at its bifurcation contracts markedly, thus protecting it from an overload.

When the capillaries are in a state of contraction, the flow remains in the main capillaries, not in the net capillaries, due to the contraction of the bifurcations of the arterial capillary.

The valves in minute veins, as well as the contractility of the small arteries, control the flow in the capillaries.

The flow in the capillaries is always controlled in the above fashion. The neuro-effectors, chemical substances and blood pressure play an important role in this mechanism.

While blood is perfused through the capillaries, its contents excepting red blood corpuscles, penetrates into, or from the tissue spaces mainly through the intercellular cement substance of the net and collecting capillaries. The penetration of these fluid and particles is influenced by the change of the permeability of the capillaries, namely the dilatation, contraction or physico-chemical change of the wall.

Variations of physical and chemical factors in the intra- and extravascular compartments will also influence the exchange of substances. The water exchange is accounted for by the alteration of hydrostatic pressure and effective osmosis. The penetration of the solute depends on the difference in concentration and electric charge, while the rate of gas exchange is governed by its partial pressure.

Whether fluid and particles penetrate into the tissue spaces or into the capillary lumen depends upon whether the above-mentioned factors act in the same or in opposite directions. The rate and direction are variable in different organs.

DISCUSSION

C. M. B. Rouget (1873) found contractile cells in the blood capillaries on tadpole's tail. An active contractility of the capillaries of frog's nictating membrane was observed by Steinach and Kahn (1903). Hooker (1921) thought that the arteriole has a wall of endothelium and circular smooth muscle only there being no adventitial sheath, but the capillary has no muscle layer. On the other hand, Krogh and Vimtrup described in 1932 that a normal capillary consists of an endothelial tube covered on the outside with branches of smooth muscle cells named after their discoverer Rouget cells, or according to some authors "pericytes." Recently, Zweifach (1949) described the remainder of the capillary wall as a denuded endothelial tube which possess no contractile elements. These are termed none muscular or true capillaries.

In our experiments, contractile cells in net capillary were found in the mesentery, but not in the lungs or liver of frogs and tortoises.

Chambers and Zweifach (1946) divided the nomenclature of the minute blood vessels into six parts from other investigator's reports. The definition of the blood capillary is not yet settled.

Hooker described alterations in the surface tension of the capillary endothelium induced by chemical or nervous influences. Field (1935) found that in the capillary contractions due to electrical stimulation of capillaries of the nictating membrane in the frog, the caliber of the vessel has been altered by folding and also by swelling of the endothelial nuclei. However, we could not observe the active contraction of endothelium of the capillaries.

The principal site of penetration is near the venous side of the capillary bed, according to the work of Landis (1934) performed on frogs, and in Rous, Gilding and Smith's investigation (1930) on rats. The pathway in the capillary wall, Chambers and Zweifach (1940) concluded, leads through the intercellular cement substance that constitutes the inter-endothelial spaces. Starling (1898) emphasized that the water exchange is greatly influenced by the colloid-osmotic pressure. Krogh (1930) called attention to the importance of the state of dilatation or contraction as influencing factors in the capillary permeability. The author's experiments fully substantiate these contentions.

Thoma (1896) and others have endeavoured to establish the pathways through which the the diapedesis of the leukocytes is effected, but the mechanism of this migration is still entirely obscure today.

When the capillary bed lost its tonus, by the perfusion of Ringer's solution, the use of adrenalin (Dale and Richards (1919)) or pituitrin (Krogh (1930)) are believed to be effective in reconstituting it. One must bear in mind, however, the fact that either one of these substances acts as a vaso-constrictor only through the stimulation of the contractile cells of the wall, hence, they can augment only the active, and not the passive tonus.

In the regulation of the capillary flow local metabolic processes are believed to be of considerable importance, according to Lewis (1927). The author, however, feels that his experiments suggest that it is the adrenalin that exerts the most important regulatory influence on the capillary blood flow.

In the resting muscles of frogs, and in warm blooded animals, closed capillaries were frequently observed by Krogh. It was also noted by Richards (1922) that in the frog's kidney, during diminished diuresis, many of the glomeruli are completely shut off from the circulation. They appear either empty or contain some stagnating red cells. This phenomenon may be attributable to the grouped contractile cells found mostly at the bifurcation. Similar observations were recently (1946) made in the bat's wing by Nicoll and Webb.

REFERENCES I

(Historical note and discussion)

1. Chambers R, Zweifach BW: Capillary endothelial cement in relation to permeability. J Cell Comp Physiol 15: 255, 1940
2. Chembers R, Zweifach BW: Functional activity of the blood capillary bed with special reference to visceral tissue. Ann NY Acad Sci 46: 683, 1946
3. Dale HH, Richards AN: The vasodilator action of histamin and of some other substances. J Physiol 52: 110, 1919
4. Field ME: The reaction of blood capillaries of the frog and rat to mechanical and electrical stimulation. Skand Arch Physiol 72: 175, 1935
5. Fulton JF: Selected Readings in the History of Physiology. Illinois, Springfield, 1930
6. Harvey W: Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus. Translated by G. Teruoka, Tokyo, Iwanami, 1628
7. Hooker DR: Evidence of functional activity on the part of the capillaries and venules. Physiol Rev 1: 112, 1921
8. Kawano K: A new fact and problem concerning the permeability of venules. Acta Path Jap 1: 1–48, 1950
9. Krogh A, Vimtrup B: Special Cytology (Cowdry). Vol 1, Section 12. Capillaries. New York, 1932
10. Krogh A: The Anatomy and Physiology of Capillaries. Yale Press 27, 1930. p 185

11. Landis EM : Capillary pressure and capillary permeability. Physiol Rev 14 : 404, 1934
12. Lewis T : The Blood Vessels of Human Skin and their Response. London, 1927
13. Nicoll PA, Webb RL : Blood circulation in the subcutaneous tissue of the living bat's wing. Ann NY Acad Sci 46 : 697, 1946
14. Richards AN : Secretion of urine. Amer J Med Sci 163 : 1, 1922
15. Rous P, Gilding HP, Smith F : The gradient of vascular permeability. J Exp Med 51 : 807, 1930
16. Starling EH : The production and absorption of lymph. In Schäfer's Text Book of Physiology 1 London, 1898. p 285
17. Thoma R : Text Book of General Pathology and Pathological Anatomy. London, 1896. p 328
18. Zweifach BW : Basic mechanisms in peripheral vascular homeostasis. Factors regulating blood pressure, 3rd Conference, 5–6 May 1949

REFERENCES II

(Papers by Dr. Nisimaru and his coworkers)

I *Methods*

1. Nisimaru Y, Sozi T : Description of the perfusion apparatus for the poikilothermal animals. Sei-I-Kai Med J 54 : 1130, 1935
2. Asami S, Tanno T : Perfusion apparatus for the homoiothermal animals. Sei-I-Kai Med J 54 : 1561, 1935
3. Sozi T : Studies on perfusion fluid for circulatory system of poikilothermal animals. Jap J Med Sci 111(7) : 295, 1941
4. Nisimaru Y, Steggerda FR : Observation of the structure and function of certain blood vessels in the spleen. J Physiol 74 : 327, 1932
5. Asami S, Inoue T, Noguchi Y : A method for the observation of blood vessel distribution. Sei-I-Kai Med J 56 : 979, 1937
6. Ogawa Y : A method for studying the distribution of blood capillaries. Seibutsu 4 : 58, 1949
7. Sinozaki N : A quantitative measurement of adrenalin and acetylcholine. J Physiol

Soc Jap 7: 675, 1942

II *Structure of the Wall*

8. Chan SY: Morphological study of the endothelial cells of small blood vessels. Sei-I-Kai Med J 55: 2486, 1936
9. Asai S: The wall cells at the bifurcation of arteriole. J Physiol Soc Jap 2: 144, 1937
10. Chan SY: Morphological study of the endothelial cells and pericyte of the small blood vessels. Sei-I-Kai Med J 56: 1532, 1937
11. Mekari S: Studies on the transverse branches in the small blood vessels. J Physiol Soc Jap 6: 659, 1941
12. Hijikata Y: Studies on the muscle cells of blood capillary walls of the turtle's lung. Teishin Igaku 5 : 309, 1953
13. Hijikata Y: Studies on the muscle cells of blood capillary walls of the turtle's brain. Teishin Igaku 5 : 313, 1953
14. Okada K: On the muscle cells of blood capillaries of the toad. J Hiroshima Med Ass 7, Original Seres 383, 1954
15. Hijikata Y: Morphological study of the endothelial cells of blood capillary walls of the turtle's lung. Teishin Igaku 5 : 293, 1953
16. Hijikata Y: Studies on the muscle cells of blood capillary walls of the turtle's liver. Teishin Igaku 5 : 245, 1953
17. Hijikata Y: Studies on the muscle cells of blood capillary walls of the turtle's mesentery. Teishin Igaku 5 : 249, 1953
18. Hijikata Y: Studies on the muscle cells of blood capillary walls of the turtle's kidney. Teishin Igaku 5 : 255, 1953
19. Katoo M: Comparative physiology of the vascular wall. (8) Blood vessel wall of the vertebrata (Cyprinus carpio, Bufo vulgaris, Clemmys japonica, Gallus domesticus). J Hiroshima Med Ass 11, Original Series 11: 1724, 1958
20. Hataya K, Kuramata H, et al: Experimental studies on the new formation of minute blood vessels. J Yokohama Munic Univ, Series C–24(94) : 83, 1958
21. Seki M: Studies on the structure of the wall of minute blood vessels. Yokohama Munic Univ, Series C–33(114) : 67, 1959

III *Distribution*

A) Nervous System

22. Tamio Y : The distribution of minute blood vessels in the carp's brain and spinal cord. J Hiroshima Med Ass 7, Original Series 340, 1954
23. Hayashi M : Studies on the vascular system of the giant salamander. 4, Distribution of the minute blood vessels in the brain and spinal cord. J Hiroshima Med Ass 9, Original Series 747, 1956
24. Tagaya S : On the distribution of minute blood vessels in the brain of the toad. J Hiroshima Med Ass 12, Original Series 1558, 1959
25. Tagaya S : On the distribution of minute blood vessels in the brain of the turtle. J Hiroshima Med Ass 12, Original Series 1554, 1959
26. Tagaya S : On the distribution of minute blood vessels in the brain of Galls domesticus. J Hiroshima Med Ass 12, Original Series 1549, 1959
27. Munechika K : Quantitative studies on the distribution of blood capillaries of cat's brain. J Hiroshima Med Ass 13, Original Series 927, 1960
28. Ishibashi A, Kawato M, Suzuki T : Distribution of minute blood vessels in Dura Mater of the human fetus. J Yokohama Munic Univ, Series C–24 (94) : 33, 1958
29. Gotoo H : Distributiont of minute blood vessels in the brain. J Yokohama Munic Univ, Series C–19(81) : 1, 1957
30. Iwata J : On the distribution of minute blood vessels surrounding the subarachnoid space. J Hiroshima Med Ass 7, Original Series 380, 1954
31. Okamoto M : The distribution of minute blood vessels of dog's dura mater. J Hiroshima Med Ass 10 : 682, 1957
32. Okamoto M : On the distribution of minute blood vessels of dog's spinal cord and ventral, dorsal nerve roots. J Hiroshima Med Ass 11, Original Series 1548, 1958
33. Okamoto M : On the distribution of minute blood vessels of dog's vago-sympathetic nerve. J Hiroshima Med Ass 11, Original Series 1544, 1958
34. Okamoto M : The distribution of minute blood vessels in the sciatic nerve. J Hiroshima Med Ass 11, Original Series 520, 1958
35. Okamoto M : The distribution of minute blood vessels of dog's superior cervical nodose and inferior mesenteric ganglia. J Hiroshima Med Ass 11, Original Series 526, 1958

36. Okamoto M: Studies on the distribution of minute blood vessels of dog's peripheral nervous system. J Hiroshima Med Ass 11, Original Series 1555, 1958

B) Eyes

37. Ootani J: The distribution of the minute blood vessels of the eye of the frog. J Hiroshima Med Ass 12, Original Series 1454, 1959

38. Ootani J: The distribution of the minute blood vessels of the eye of Clemmys japonica. J Hiroshima Med Ass 12, Original Series 1457

39. Ootani J: The distribution of the minute blood vessels of the eye of Gallus domesticus. J Hiroshima Med Ass 12, Original Series 1450

40. Suzuki T: Distribution of the minute blood vessels in the eyeball of human fetus. J Yokohama Munic Univ, Series C–24(94) : 7, 1958

41. Suzuki T, Takahashi T, Kawato M: Some findings on minute blood vessels in the lacrimal gland of human fetus. J Yokohama Munic Univ, Series C–24(94) : 43, 1958

C) Ear and Nose

42. Satoo R: Studies on the distribution of blood capillaries in the mucous membrane of middle ear, nose and eyelid. J Hiroshima Med Ass 4 : 620, 1951

43. Satoo Y: Studies on the distribution of blood capillaries in the internal ear. Sei-I-Kai Med J, Vol 66, 1951

44. Satoo Y: Studies on the distribution of blood capillaries in the middle ear. Sei-I-Kai Med J, Vol 66, 1951

45. Satoo Y: Studies on the distribution of blood capillaries on the wall of nasal cavity. Sei-I-Kai Med J, Vol 66, 1951

46. Satoo Y: Studies on the distribution of blood capillaries in the mucous membrane of tongue. Sei-I-Kai Med J Vol 66, 1951

47. Satoo Y: Studies on the distribution of blood capillaries in the mucous membrane of larynx. Sei-I-Kai Med J Vol 66, 1951

D) Respiratory Organs

48. Manabe S: Studies on the distribution of the blood capillaries on the lungs. Jap J Surg 51 : 671, 1951

49. Tamio Y: The distribution of minute blood vessels on the air-bladder of carp. J Hiroshima Med Ass 5, Suppl: 602, 1952

50. Tamio Y: The distribution of minute blood vessels of the gills of carp. J Hiroshima Med Ass 5, Suppl: 599, 1952

51. Nakayama Y: Studies on the minute blood vessels distribution in the lungs. J Yokohama Munic Univ, Series C-8(32) : 1, 1954

52. Hiraga A: Distribution of the minute blood vessels of lung in the triturus pyrrhogaster. J Hiroshima Med Ass 8, Origianal Series 67, 1955

53. Hiraga A: Distribution of the minute blood vessels of lung in the megalobatrachus. J Hiroshima Med Ass 8, Original Series 70, 1955

54. Hiraga A: Distribution of the minute blood vesels of lung in the Bufo vulgaris japonica and Rana nigromaculata. J Hiroshima Med Ass 8, Original Series 74, 1955

55. Hiraga A: Distribution of the minute blood vessels of lung in the Gekko japonicus. J Hiroshima Med Ass 8, Original Series 79, 1955

56. Hiraga A: Distribution of the minute blood vessels of lung in the Clemmys japonica. J Hiroshima Med Ass 8, Original Series 83, 1955

57. Hiraga A: Distribution of the minute blood vessels of lung in the Golumba liva domestica. J Hiroshima Med Ass 8, Original Series 87, 1955

58. Hiraga A: Distribution of the minute blood vessels of lung in the Passeriformes montanus saturatus. J Hiroshima Med Ass 8, Original Series 92, 1955

59. Hiraga A: Distribution of the minute blood vessels of lung in the Gallus domesticus. J Hiroshima Med Ass 8, Original Series 95, 1955

60. Hiraga A: Distribution of the minute blood vessels of lung of the Cavia cobaya. J Hiroshima Med Ass 8, Original Series 99, 1955

61. Sho Y, Inomata T, Suzuki Y: On the communication between pulmonary blood vessel and bronchial blood vessels. Tokyo Jikeikai Med J 7 : 2196, 1957

E) Teeth

62. Hada J: On the distribution of minute blood vessels in the teeth and jaw of the Cyprinus carpiro. J Hiroshima Med Ass 11, Original series 1568, 1958

63. Hada J: The distribution of minute blood vessels in the frog's teeth and jaw. Hiroshima Med Ass 9, Original Series 42, 1956

64. The distribution of minute blood vessels in the teeth and jaw of newt. J Hiroshima Med Ass 10, Original Series 708, 1957

65. Hada J : The distribution of minute blood vessels in the chitin and jaw of tortoies. J Hiroshima Med Ass 10, Original Series 711, 1957

66. Hada J : Distribution of the minute blood vessels in the teeth and jaw of Natrix tigrina. J Hiroshima Med Ass 9, Original Serise 661, 1956

67. Hada J : On the distribution of minute blood vessels in the teeth and jaw of Eumeces latiscutatus. J Hiroshima Med Ass 11, Original Series 1564, 1958

68. Hada J : The distribution of minute blood vessels in the teeth and jaw of rat. J Hiroshima Med Ass 10, Original Series 699, 1957

69. Hada J : On the distribution of minute blood vessels of the teeth and jaw of Felis domestica. J Hiroshima Med Ass 12, Original Series 570, 1959

F) Alimentary Canal

70. Hayashi M : Distribution of the minute blood vessels in the palate of giant salamander. 6. J Hiroshima Med Ass 9, Original Series 757, 1956

71. Hiraga A : The distribution of minute blood vessels in the palate of Bufo japonica. J Hiroshima Med Ass 7, Original Series 350, 1954

72. Satoo R : Studies on the distribution of blood capillaries in the oral cavity and its surroundings. (Continued) J Hiroshima Med Ass 3 : 165, 1950

73. Satoo R : Studies on the distribution of blood capillaries in the oral cavity and its surroundings. Part 1. Bull Hiroshima Med Sch 2 : 313, 1950

74. Satoo R : Studies on the distribution of blood capillaries in the oral cavity and its surroundings. Part 2. J Hiroshima Med Ass 4 : 45, 1951

75. Gotoo T : The distribution of blood capillaries in the oral cavity and its surroundings. 1. Mucous membrane of the dog's tongue. J Hiroshima Med Ass 10, Original Series 685, 1957

76. Gotoo T : The distribution of blood capillaries in the oral cavity and its surroundings. 2. Palatine tonsil of the dog. J Hiroshima Med Ass 10, Original Series 693, 1957

77. Gotoo T : The distribution of blood capillaries in the oral cavity and its surroundings. 3. Mandibular articulation of the dog. J Hiroshima Med Ass 10, Original Series 739, 1957

78. Gotoo T : The distribution of blood capillaries in the oral caviy and its surroundings. 4. Teeth and its surroundings of dog. J Hiroshima Med Ass 11, Original

Series 550, 1958
79. Hayashi M: Distribution of the minute blood vessels in the tongue of giant salamander. J Hiroshima Med Ass 9; Original Series 753, 1956
80. Hiraga A: The distribution of minute blood vessels in the tongue of Bufo japonica. J Hiroshima Med Ass 7, Original Series 348. 1954
81. Tamio Y: The distribution of the minute blood vessels in the oesophagus of carp. J Hiroshima Med Ass 5, Suppl: 593, 1952
82. Hayashi M: Distribution of the minute blood vessels in the oesophagus of giant salamander. J Hiroshima Med Ass 9, Original Series 761, 1956
83. Hiraga A: Distribution of minute blood vessels in the oesophagus of Bufo japonica. J Hiroshima Med Ass 7, Original Series 352, 1954
84. Ogawa Y: Studies on the distribution of blood capillaries in the mucous membrane of oesophagus. J Physiol Soc Jap 11 : 57, 1949
85. Sakai T: On the distribution of blood capillaries in the oesophagus. J Hiroshima Med Ass 12, Original Series 352, 1959
86. Hayashi M: Distribution of the minute blood vessels in the stomach of giant salamander. J Hiroshima Med Ass 9, Original Series 4; 765, 1956
87. Hiraga A: The distribution of minute blood vessels of the stomach of Bufo iaponica. J Hiroshima Med Ass 7, Original Series 354, 1954
88. Ogawa Y: Studies on the distribution of blood capillaries of mucous membrane of the stomach. J Physiol Soc Jap 11 : 60, 1949
89. Sakai T: On the distribution on minute blood vessels in the stomach. J Hiroshima Med Ass 12, Original Series 355, 1959
90. Nishi T: On the distribution of the minute blood vessels in the digestive organs of Anguilla japonica. J Hiroshima Med Ass 13, Original Series 353, 1960
91. Tamio Y: The distribution of minute blood vessels in the carp's intestines. J Hiroshima Med Ass 7, Original Series 337, 1954
92. Hayashi M: Distribution of the minute blood vessels in the upper intestines of giant salamander. J Hiroshima Med Ass 9, Original Series 771, 1956
93. Hayashi M: Distribution of the minute blood vessels in the lower intestines of giant salamander. J Hiroshima Med Ass 9, Original Series 779, 1956
94. Nishi T: On the distribution of the minute blood vessels in the digestive organs

of Rana nigromaculata Hall. Hiroshima Med Ass 13, Original Series 357, 1960

95. Hiraga A : The distribution of minute blood vessels in the large intestine of Bufo japonica. J Hiroshima Med Ass 7, Original Series 358, 1954
96. Hiraga A : The distribution of minute blood vessels in the small intestines of Bufo japonica. J Hiroshima Med Ass 7, Original Series 356, 1954
97. Nishi T : On the distribution of the minute blood vessels in the digestive organs of Clemmys japonica. J Hiroshima Med Ass 13, Original Series 371, 1960
98. Nishi T : On the distribution of the minute blood vessels in the digestive organs of Rattus norveficus albus. J Hiroshima Med Ass 13, Original Series 364, 1960
99. Ogawa Y. Studies on the distribution of blood capillaries in the mucous membrane of intestines. J Physiol Soc Jap 11 : 66, 1949
100. Sakai T : On the distribution of minute blood vessels in the small intestine. J Hiroshima Med Ass 12, Original Series 358, 1959
101. Noguchi Y : Study on the distribution of small blood vessels in the rabbit's vermiform process. Sei-I-Kai Med J 57 : 2014, 1938
102. Ogawa Y : Studies on the distribution of blood capillaries in the mucous membrane of the colon. J Physiol Soc Jap 11 : 97, 1949
103. Sakai T : On the distribution of minute blood vessels of the large intestine. J Hiroshima Med Ass 12, Original Series 363, 1959
104. Gotoo T : A summary of the studies on the blood capillaries in the oral cavity and its surroundings. J Hiroshima Med Ass 12, Original Series 1441, 1959
105. Kusunoki M : A comparative study on the distribution of blood capillary in the digestive organ of vertebrates. J Hiroshima Med Ass 12, Original Series 779, 1959
106. Ogawa Y : Summary of studies on the distribution of blood cappillaries in the alimentary tract. J Physiol Soc Jap 11 : 104, 1949
107. Kawato M : Distribution of minute blood vessels in the digestive system of human embryo. J Yokohama Munic Univ, Series C-24 (94) : 91, 1958

G) Liver and Gall Bladder

108. Hayashi M : Distribution of the minute blood vessels of the liver of giant salamander. J Hiroshima Med Ass 9, Original Series 783, 1956
109. Manabe S : The distribution of the blood capillaries on the liver. J Hiroshima Med Ass 4 : 202, 1951

110. Watanabe K: Studies on the distribution of the minute blood vessels of the liver. J Yokohama Munic Univ, C-33 (114): 1, 1959

111. Nishimaru Y: Blood and lymph vessels in the liver. In Liver Diseases. Shindan to Chiryoo-sha, 1955

112. Ogawa Y: Studies on the distribution of blood capillaries in the mucous membrane of gall bledder. J Physiol Soc Jap 11 : 102, 1949

113. Tamio Y: The distribution of minute blood vessels in the gall bladder of carp. J Hiroshima Med Ass 5, Suppl: 604, 1952

114. Hiraga A: The distribution of minute blood vessels in the gall bladder of Bufo japonica. J Hiroshima Med Ass 7, Original Series 361, 1954

115. Hayashi M: Distribution of the minute blood vessels in the gall bladder of giant salamander. J Hiroshima Med Ass 9, Original Series 785, 1956

116. Sakai T: On the distribution of minute blood vessels in the gall bladder. J Hiroshima Med Ass 12, Original Series 368, 1959

H) Kidney

117. Tamio Y: The distribution of minute blood vessels on the carp's kidneys. J Hiroshima Med Ass 5, suppl: 1952

118. Kodama S: The argentophil fibers of toad's kidney. J Hiroshima Med Ass 10, Original Series 733, 1957

119. Hayashi M: Distribution of the minute blood vessels in the kidney of giant salamander. J Hiroshima Med Ass 9, Original Series 793, 1956

120. Matsumoto K: On the distribution of the minute blood vessels in the kidneys of the Japanese toad. J Hiroshima Med Ass 12, Original Series 1532, 1959

121. Matsumoto K: On the distribution of the minute blood vessels in the kidneys of Clemmys japonica. J Hiroshima Med Ass 12, Original Series 1536, 1959

122. Matsumoto K: On the distribution of the minute blood vessels in the kidneys of Gallus domesticus. J Hiroshima Med Ass 12, Original Series 1540, 1959

123. Yamamoto A: The distribution of the minute blood vessels in the kidneys. J Hiroshima Med Ass 7, Original Series 362, 1954

I) Endocrine Organs

124. Manabe S: Studies on the distribution of blood capillaries in the carotis gland. J Hiroshima Med Ass 2 : 332, 1949

125. Ogawa Y, Satoo Y: Studies on the distribution of blood capillaries in the pituitary body. Seitai no Kagaku 1 : 140, 1949

126. Oomura H: Studies on the distribution of minute blood vessels in the adrenal gland. J Chiba Med Soc 30 : 64, 1954

127. Okita M: Distribution of the minute blood vessels in the internal secretory organs. J Hiroshima Med Ass 8, Original Series 235, 1955

128. Hayashi M: Distribution of the minute blood vessels in the pancreas of giant salamander. J Hiroshima Med Ass 9, Original Series 787, 1956

129. Kihara Y, Sakai T: Distribution of the blood capillaries of fetal thymus. J Hiroshima Med Ass 9, Original Series 601, 1956

130. Nisimaru Y: Suprarenal gland and its blood vessels. Nippon Rinshoo 14 : 28, 1956

131. Higaki F, Ochiai Y, Kodama S: Th distribution of minute blood vessels in the thyroid gland. J Hiroshima Med Ass 10, Original Series 736, 1957

132. Yamada Y, Kakita K: Distribution of minute blood vessels in the carotid body. J Yokohama Munic Univ, Series C–24(94) : 1, 1958

133. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the thymus. J Hiroshima Med Ass 12, Original Series 1469, 1959

134. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the thyroid gland. J Hiroshima Med Ass 12, Original Series 1474, 1959

135. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the pancreas. J Hiroshima Med Ass 12, Original Series 1478, 1959

136. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the testis. J Hiroshima Med Ass 12, Original Series 1482, 1959

137. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the adrenal gland. J Hiroshima Med Ass 12, Original Series 1487, 1959

138. Yorishima A: Comparative studies on the distribution of the minute blood vessels in the pituitary bodies. J Hiroshima Med Ass 12, Original Series 1492, 1959

J) Uro-genital Organs

139. Satoo R: Studies on the distribution of the blood capillaries in urethra, vagina and bladder. J Hiroshima Med Ass 4 : 622, 1951

140. Andoo Y, Yamashita R: The distribution of minute blood vessels in the normal rabbit's uterus. J Hiroshima Med Ass 5, Suppl 605, 1952

141. Andoo Y, Yamashita R: The distribution of minute blood vessels of the pregnant uterus of rabbit. J Hiroshima Med Ass 5, Suppl 610, 1952

142. Yamamoto A: The distribution of minute blood vessels in the renal pelvis, ureter and urinary bladder. J Hiroshima Med Ass 7, Original Series 368, 1954

143. Yamamoto A: The distribution of minute blood vessels in the urethra and penis. J Hiroshima Med Ass 7, Original Series 371, 1954

144. Yamamoto A: The distribution of minute blood vessels in the prostate, seminal vesicle, vas deferens, testis and epididymis. J Hiroshima Med Ass 7, Original Series 374, 1954

145. Hayashi M: Distribution of the minute blood vessels in the seminal gland of giant salamander. J Hiroshima Med Ass 9, Original Series 799, 1956

146. Hayashi M: Distribution of the minute blood vessels in the ovarium of giant salamander. J Hiroshima Med Ass 9, Original Series 803, 1956

147. Hayashi M: Distribution of the minute blood vessels in the oviduct of giant salamander. J Hiroshima Med Ass 9, Original Series 807, 1956

148. Hayashi M: Distribution of the minute blood vessels in the urinary bladder of giant salamander. J Hiroshima Med Ass 9, Original Series 811, 1956

149. Asao K: On the distribution of the minute blood vessels in the female sexual organs of toards. J Hiroshima Med Ass 12, Original Series 1513, 1959

150. Asao K: On the distribution of the minute blood vessels in the female sexual organs of tortoise. J Hiroshima Med Ass 12, Original Series 1509, 1959

151. Asao K: Studies on the distribution of the minute blood vessels in the female sexual organs of domestic fowl. J Hiroshima Med Ass 12, Original Series 1504, 1959

152. Asao K: On the distribution oi the minute blood vessels in the female sexual organs. J Hiroshima Med Ass 12, Original Series 1499, 1959

153. Negitaya M: Studies on the distribution of minute blood vessels in the female genital organs. J Yokohama Munic Univ, Series C-33, 157

K) Skin

154. Nisimaru Y, Ogawa Y: Studies on the distribution of minute blood vessels in

the skin. Nisshin Igaku 34 : 242, 1947

155. Satoo R: Studies on the distribution of blood capillaries in the skin. J Hiroshima Med Ass 4 : 623, 1951

156. Tamio Y, Hiraga A, et al: Distribution of the blood capillaries of human skin of foot. J Hiroshima Med Ass 7, Original Series 641, 1954

157. Tamio Y: The distribution of minute blood vessels in the carp's skin. J Hiroshima Med Ass 7, Original Series 335, 1954

158. Kihara Y: Blood capillaries of the fetal skin. J Hiroshima Med Ass 9, Original Series 565, 1956

159. Hayashi M: Distribution of the minute blood vessels in the skin of salamander. J Hiroshima Med Ass 9, Original Series 741, 1956

160. Yamada Y: Studies on the distribution of minute blood vessels in the human skin. J Yokohama Munic Univ, Series D-21 (83) : 1, 1958

L) Muscle and Joint

161. Satoo R: Studies on the distribution of blood capillaries in the muscle risorius. J Hiroshima Med Ass 4 : 619, 1951

162. Manabe S: The distribution of blood capillaries in the muscles. J Hiroshima Med Ass 5 : 132, 1951

163. Tamio Y: The distribution of minute blood vessels in the carp's muscles. J Hiroshima Med Ass 7, Original Series 332, 1954

164. Hayashi M: Distribution of the minute blood vessels in the skeletal muscle of giant salamander. J Hiroshima Med Ass 9, Original Series 745, 1956

165. Ochiai Y: Kodama S, Okuhiro S: On the distribution of the blood capillaries in the joints of vertebra. J Hiroshima Med Ass 11, Original Series 1579, 1958

Vascular Wall

166. Kishi Y: On the distribution of minute blood vessels on the blood and lymph vessel walls. J Hiroshima Med Ass 5, Suppl 614, 1952

M) Summary

167. Tagaya S: Studies concerning the comparative physiology of minute blood vessels in the central nervous system. J Hiroshima Med Ass 12, Original Series 1565, 1959

168. Ootani J: Studies concerning the comparative physiology of minute blood vessels

of the visual organs. J Hiroshima Med Ass 12, Original Series 1466, 1959

169. Satoo Y: Summary of the experiments on the distribution of blood capillaries on the ear, nose, pharynx and larynx. Sei-I-Kal Med J, 66, 1951

170. Hiraga A: Summary of comparative studies on the body fluid flow in the gills and lungs. J Hiroshima Med Ass 8, Original Series 103, 1955

171. Hada J: Studies on the distribution of minute blood vessels in the teeth and jaw of animals. J Hiroshima Med Ass 12, Original Series 578, 1959

172. Satoo R: Summary of the experiments on the distribution of blood capillaries in the oral cavity and its surroundings. Bull Hiroshima Med Sch 3 : 377, 1951

173. Sakai T: A summary of the studies on the distribution of minute blood vessels in the digestive organs. J Hiroshima Med Ass 12, Original Series 370, 1959

174. Nishi T: A summary of the comparative studies on the distribution of the minute blood vessel of the digestive organs on the several vertebrates. J Hiroshima Med Ass 13, Original Series 378, 1960

175. Matsumoto K: Studies concerning the comparative physiology of the minute blood vessels of the kidney. J Hiroshima Med Ass 12, Original Series 1544, 1959

176. Asao K: Summary of the studies of comparative physiology of the blood capillaries in the female genital organs. J Hiroshima Med Ass 12, Original Series 1517, 1959

177. Yamamoto A: A summary of the studies on the distribution of male urogenital organs. J Hiroshima Med Ass 7, Original Series 377, 1954

178. Satoo R: Summary of the experiments on the distribution of blood capillaries in the skin and mucous membrane. J Hiroshima Med Ass : 4626, 1951

179. Manabe S: The consideration on the distribution of blood capillaries. J Hiroshima Med Ass 4 : 203, 1951

180. Tamio Y: Studies on the distribution in the minute blood vessels of carp. J Hiroshima Med Ass 7, Original Series 343, 1954

181. Arai T: Studies on density of distribution of the minute blood vessels. J Yokohama Munic Univ, Series C-32 (105) : 1, 1959

182. Ogawa Y: Studies on the minute blood vessel distribution. J Yokohama Munic Univ, C-6 (12) : 1, 1952

V *Vascular Nerve*

183. Nisimaru Y: Studies on the vaso-motor nerve to the frog's hind limbs. Sei-I-Kai Med J 41 : 231, 1922
184. Semba T: Studies on the vaso-dilatation of hind limbs caused by excitation of sciatic nerve. J Physiol Soc Jap 5 : 379, 1941
185. Semba T: Relationship between the cutting of anterior and posterior roots of spinal nerve and calibre of small blood vessels of frog's web. J Physiol Soc Jap 7 : 444, 1942
186. Noda H: Medullary vasomotor centers of frog's web. J Hiroshima Med Ass 12, Original Series 307, 1959
187. Semba T: A few experiments on the vasodilatation of tongue. J Hiroshima Med Ass 113, 1949
188. Semba T: Studies on the vasodilatation of tongue caused by nerve stimulation. J Hiroshima Med Ass 80, 1949
189. Semba T: Studies on the vaso-motor reflex to the blood capillaries. J Physiol Soc Jap 11 : 8, 1948
190. Irisawa H: Studies on the vaso-motor reflex from the blood capillary of one side web to the blood capillary of the opposite side web. J Physiol Soc Jap 11 : 22, 1948
191. Semba T: Studies on the vascular reflexes from the abdominal cavity to the web. J Physiol Soc Jap 13 : 175, 1951
192. Semba T, Irisawa H: Studies on the vascular reflexes. Sei-Tai no Kagaku 2 : 213, 1951
193. Samba T: Studies on the vascular reflexes of hind limbs. J Hiroshima Med Ass 5 : 28, 1952
194. Naitoo Y: Studies on the vaso-reflex of the mesentery by the central stimulations of the sensory nerves. Hiroshima Med Ass 7, Original Series 432, 1954
195. Nisimaru Y: Studies on the vaso-motor nerves. J Hiroshima Med Ass 19 : 3, 1966

VI *Contractility*

A) Physical and Chemical Stimulus

196. Chan SY: The reactions of blood vessels to the temperature. Sei-I-Kai Med J 54 : 1014, 1935

197. Sozi T: Studies on the influence of the physico-chemical factors of the blood on the contractility of blood vessels. Sei-I-Kai Med J 44 : 2246, 1935

198. Sozi T: Influence of phosphate on the contractility of blood vessels. Sei-I-Kai Med J 55 : 125, 1936

199. Chan SY: The actions of novocaine and temperature on the blood vessels. Sei-I-Kai Med J 55 : 2493, 1936

200. Kiuti S: Action of some drugs on the contractility of small blood vessels. Sei-I-Kai Med J 57 : 2434, 1938

201. Shinozaki N: The actions of acetylcholine and histamine to the minute blood vessels. J Physiol Soc Jap 8 : 487, 1943

202. Ichikawa S: The actions of K and Ca ions to the blood vessels. J Physiol Soc Jap 8 : 684, 1943

203. Hukuba T: Influences on the small blood vessels by temperature. J Physiol Soc Jap 9 : 704, 1944

204. Hukuba T: Studies on the vascular reaction caused by temperature. J Hiroshima Med Ass 2 : 18, 1949

205. Shinozaki N: Studies on the actions of adrenalin and pituitrin to the blood flow in the capillary. J Physiol Soc Jap 9 : 413, 1943

206. Iwata J: Studies of actions of drugs on the contractility of cerebral blood vessels. J Hiroshima Med Ass 4 : 487, 1951

207. Murakami H, Iizuka T: The action of urethane on the blood vessels. J Hiroshima Med Ass 6 : 454, 1953

208. Hiraga H: The action of acetylcholine upon the blood vessels of the hind limbs of frog. J Hiroshima Med Ass 6 : 437, 1953

209. Hayashi M: The effect of noradrenalin on the blood vessels of frog's web and mementery. J Hiroshima Med Ass 11, Original Series 517, 1958

B) Contractility

210. Yokoyama T: On the study on the automatic contraction of capillaries. Sei-I-Kai Med J 55 : 1178, 1936

211. Kiuti S: Studies on the tonus of small blood vessels. J Physiol Soc Jap 3 : 47, 1938

212. Kiuti S: Studies on the elasticity of small blood vessels. J Physiol Soc Jap 3 :

304, 1938

213. Kiuti S, Niizuma Y: Independent contractility of the small blood vessels. Sei-I-Kai Med J 57 : 2427, 1938

214. Kiuti S: Studies on the extensibility of arteriole. J Physiol Soc Jap 4 : 12, 1939

215. Koono M: Studies on the contractility at the bifurcation of arteriole. Sei-I-Kai Med J 58 : 18, 1939

216. Kiuti S: Studies on the contractility of blood capillary. J Physiol Soc Jap 4 : 189, 1939

217. Semba T: Studies on the contractility of small blood vessels caused by changing its inner pressure. J Physiol Soc Jap 7 : 178, 1942

218. Irisawa H: Studies on the rhythmical contraction of blood capillaries. J Physiol Soc Jap 11 : 19, 1948

219. Ichikawa S: Studies on the pressure proof of blood capillaries. J Physiol Soc Jap 10 : 103, 1946

220. Iwata J: Passive contractility of the blood vessels of the brain and lower limbs. J Hiroshima Med Ass 7, Original Series 392, 1954

221. Shigematsu M: The contractility of the blood capillaries. J Physiol Soc Jap 7 : 147, 1939

222. Naitoo Y: On the contractility of mesenteric blood vessels of the dogs. J Hiroshima Med Ass 7, Original Series 954, 1954

Summary

223. Nisimaru Y: Summary of our studies on the contractility and permeability of small blood vessels. Syokubutu and Doobutu 7(649) : 813, 1939

224. Nisimaru Y: On the contractility of small blood vessels. Jap J Med Sci 3(8) : 31, 1942

225. Iwata J: Angiophysiological studies on the brain. J Hiroshima Med Ass 7, Original Series 625, 1954

VII *Permeability*

A) Physical and chemical stimulus

226. Inoue T, Kiuti S: Relationship between the osmotic pressure and the permeability of blood capillary wall. Sei-I-Kai Med J 54 : 1132, 1935

227. Inoue T, Motizuki K: Relationship between the permeability of capillary wall

and the viscosity of perfusion fluid. Sei-I-Kai Med J 54 : 1136, 1935

228. Inoue T: The action of ions on the permeability of dyes through the blood vessel wall. Sei-I-Kai Med J 54 : 2103, 1935

229. Kiuti S: The actions of adrenalin, pituitrin and histamine on the permeability of dyes through the blood vessel wall. Sei-I-Kai Med J 55 : 1354, 1936

230. Kiuti S: The influences of pH and temperature on the permeability of dyes through the small blood vessel wall. Sei-I-Kai Med J 55: 1565, 1936

231. Koono M: Influences of adrenalin, pituitrin and histamine on the water exchange through the wall of blood vessels. Sei-I-Kai Med J 57 : 511, 1938

232. Nishida Y, Andoo Y: Studies on the influences for the permeability and diffusion of a dye by hyaluronidase. J Hiroshima Med Ass 5 : 460, 1952

B) Permeability of Water

233. Tanno T: A method for observing the permeability of water through the blood vessel wall. Sei-I-Kai Med J 55 : 1556, 1936

234. Tanno T: The exchange of water through the blood vessel walls. Sei-I-Kai Med J 55 : 2625, 1936

235. Tanno T: Relationship between osmotic pressure and edema. Sei-I-Kai Med J 56 : 787, 1937

236. Tanno T: The osmotic phenomena of permeable membrane. J Physiol Soc Jap 2 : 53, 1937

237. Tanno T: A few experiments on the influence of osmotic pressure to the water exchange through the blood vessel wall. Sei-I-Kai Med J 56 : 1540, 1937

238. Tanno T: Some effects of osmotic pressure on the red blood corpuscle. Sei-I-Kai Med J 57 : 859, 1938

239. Tanno T: Effective osmotic pressure of colloid through the wall of the blood vessels. Sei-I-Kai Med J 57 : 1566, 1938

240. Tanno T: A new conception of the osmotic phenomenon. J Physiol Soc Jap 5: 207, 1940

241. Yokoyama T: Studies on the water exchange through the blood vessel walls. Sei-I-Kai Med J 59 : 1026, 1940

242. Hagiwara H: Action of acetylcholine on the permeability of capillary walls. J Hiroshima Med Ass 5, Suppl 627, 1952

243. Iwata J: On the water permeation to the brain through the blood vessel walls. J Hiroshima Med Ass 7, Original Series 2 : 622, 1954

C) Mechanism

244. Asai S, Nisimaru Y: Studies on the permeability of the blood vessel walls. Nippon Izi Sinpoo 576, 1933

245. Asai S, Dodo Y: Studies on the blood vessels of tadpole. J Physiol Soc Jap 1 : 266, 1936

246. Kiuti S: The function of blood capillary wall on the permeability of dye. Sei-I-Kai Med J 55 : 569, 1936

247. Yokoyama T: Study on the permeability of dyes through the arteriole, capillaries and venose. Sei-I-Kai Med J 55 : 2028, 1936

248. Motizuki K: The permeability of starch particles through the blood vessels. Sei-I-Kai Med J 55 : 2228, 1936

249. Kiuti S: The mechanism of permeability of dyes through the blood capillary wall. Sei-I-Kai Med J 56 : 255, 1937

250. Motizuki K: Permeability of starch through the blood vessel walls (II). Sei-I-Kai Med J 57 : 1147, 1938

251. Sozi T: Relationships between the calibre of small blood vessels and the osmotic pressure. J Physiol Soc Jap 5 : 386, 1941

252. Motizuki K: Studies on the permeability of dyes in the tubules of kidney and of other tissues in the various parts of the body. J Physiol Soc Jap 7 : 635, 1942

253. Iwata J: Isoelectric point of the wall of cerebral blood capillaries. J Hiroshima Med Ass 6, Suppl 3 : 94, 1953

254. Iwata J: On the permeability of cerebral blood vessels. J Hiroshima Med Ass 7, Original Series 409, 1954

255. Reaction of the local blood capillaries with an experimental burn. J Hiroshima Med Ass 7, Original Series 414, 1954

256. Booda K: On the permeability of dyes and water to the blood capillary and urinary bladder walls. J Hiroshima Med Ass 7, Original Series 963, 1954

257. Nisimaru Y: Elimination of dyes through the kidneys. Okayama Igakkai Zasshi 40 : 1383, 1928

258. Inoue T: Studies on the permeability of Bowman's capsule in the kidney. (I)-

(V). Sei-I-Kai Med J 56 : 1866, 1937

259. Motizuki K : The relationship between the permeability of the Bowman's capsule and its perfusion pressure. Sei-I-Kai Med J 58 : 325, 1939
260. Uozumi S : Studies on the elimination of Congo red from the kidney's tubules. Sei-I-Kai Med J 62 : 491, 1943
261. Nisimaru Y : Elimination of dyes through the liver. Okayama Igakkai Zasshi 40 : 1064, 1928
262. Nisimaru Y : Studies of the function of the liver. Okayama Igakkai Zasshi 40 : 1941, 1928
263. Nisimaru Y : Bile pigment formation of the liver. Amer J Physiol 97 : 654, 1931
264. Nisimaru Y, Hatta H : Liver lymph and its lymphatics. Saishin Igaku 11 : 377, 1956
265. Nisimaru Y : Blood and lymph vessels and fluid flow int the spleen. Bull Hiroshima Jogakuin Coll 13 : 71, 1963
266. Nisimaru Y : On the blood and lymph vessels of kidneys. J Jap Urol Sci 55 : 715, 1964
267. Nisimaru Y : Blood and lymph vessels and fluid flow in the lung. Bull Hiroshima Jogakuin Coll 15 : 131, 1965
268. Nisimaru Y : Blood and lymph vessels and fluid flow in the liver. J Hiroshima Med Ass 19 : 251, 1966

Summary

269. Nisimaru Y : Permeability of blood and lymph capillaries. Ketsuekigaku Symposium, Nov 1949
270. Nisimaru Y : On the permeability of the wall of small blood vessels. Jap J Med Sci 3(8) : 49, 1942

VIII *Blood Flow*

A) Regulation

271. Koono M : Study on the glomerular circulation of the frog's kidney. Tokyo Iji Shinshi 2904, 1934
272. Yokoyama T : Blood circulation in the muscle. Sei-I-Kai Med J 55 : 434, 1936
273. Hagiwara H : Studies on the regulation of the blood flow in the glomerulus of the kidney. J Hiroshima Med Ass 1 : 18, 1948

274. Nisimaru Y, Watanabe T, Semba T : Studies on the regulation of blood flow in the small blood vessels. J Physiol Soc Jap 7 : 761, 1942

275. Nakahara I : Studies on the blood flow in the muscle. J Physiol Soc Jap 8 : 688, 1943

276. Barcroft J, Benatte A, Greeson CE, Nisimaru Y : The rate of blood flow through cyanosed skin. J Physiol 73 : 344, 1931

277. Hukuba T : On the relationship between the surface temperature of the skin and the blood vessels. J Physiol Soc Jap 13 : 216, 1951

278. Hukuba T : Studies on the blood flow in the capillaries after the resection of heart. J Hiroshima Med Ass 3 : 202, 1950

279. Hagiwara H : Blood flow in the skeletal muscle. J Hiroshima Med Sci 1 : 1, 1952

280. Hagiwara H : Studies on the blood flow during the prolinged tetanus of skeletal muscle. J Hiroshima Med Ass 5, Suppl 621, 1952

281. Okita M, Irisawa H : Studies on the rate of blood flow through the blood capillaries. J Physiol Soc Jap 14 : 98, 1952

282. Booda K : Relationships between the inner pressure ot urinary bladder and its blood circulation. J Hiroshima Med Ass 7, Original Series 2 : 960, 1954

283. Kakita K : Studies on the arterio-venous anastomosis. (Part 1) Basic pattern. J Physiol Soc Jap 19 : 897, 1957

284. Kakita K : Studies on the arterio-venous anastomosis. (Part 2) Some experiments on the arterio-venous anastomosis. J Physiol Soc Jap 20 : 123, 1958

285. Kakita K : Studies on arterio-venous anastomosis. (Part 3) Arterio-venous anastomosis in various organs. J Yokohama Munic Univ, Series C-24 (94) : 51, 1958

286. Kakita K : Studies on arterio-venous anastomosis. (Part 4) Summary of the studies on arserio-venous anastomosis. J Yokohama Munic Univ, Series C-24(94) : 73, 1958

287. Ogawa Y, Yusa S, et al : A study of arterio-venous anastomoses. J Yokohama Munic Univ, Series C-48(160) : 1, 1966

288. Toodoo N : On the valve and blood flow in the minute vein. Teishin Igaku 6 : 441, 1954

289. Toodoo N : On the valve and blood flow in the minute vein. Part 2. Teishin Igaku 7 : 241, 1955

B) Summary

290. Nisimaru Y: Studies on the regulation of blood flow in the blood capillaries. Shokubutsu and Doobutsu 11 : 455, 1943

291. Hijikata Y: Studies on the function and structure of the blood capillaries. J Hiroshima Med Ass 6, Suppl 342, 1953

IX *General Description*

292. Nisimaru Y: The physiology of blood capillaries. Nissin Igaku 33 : 143, 1944

293. Nisimaru Y: Conception of the blood and lymph capillaries. Nippon Junkanki Gakushi 13 : 75, 1948

294. Nisimaru Y: Studies on the blood and lymph capillaries. Igaku Tsushin 3 : 131, 1948

295. Nisimaru Y: Summary of our studies on the blood capillaries. Igaku no Ayumi 16 : 221, 1953

296. Studies concerning the physiological behavior of blood capillaries. Hiroshima J Med Sci 4 (2–3) 1955

〔要　約〕

毛細血管の構造と機能についての研究総括

西　丸　和　義

この論文は毛細血管の構造と機能を無脊椎動物、両棲類、は虫類、哺乳動物と人体について実験追及した、協同研究者との論文296編をまとめたものである。

これによって得た毛細血管の概念は、

毛細血管では、その壁の受動的および能動的収縮性に基因して血行調節が行なわれ、またその壁の透過性、およびこれを境とする血液と組織液との間の物理化学的性状の差異に基因して両液間の物質交換が行なわれるのものである。