THE EFFECT OF CHANGES IN TEMPERATURE UPON THE VISCOSITY OF THE "LIVING" BLOOD.[1]

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It has been shown in an earlier paper of this series [2] that the viscosity of defibrinated blood can be changed by varying the temperature. While a rise in the temperature produces a decrease, a fall in the temperature causes an increase of the "molecular" friction of the blood. The question now arises, does the viscosity of the "living" blood vary in a similar manner, or better, is it possible to alter the viscosity of the circulating blood by changing the temperature of the surrounding medium?

To solve this question I performed a series of experiments upon dogs in accordance with the method described by Hürthle.[3] By means of this method it is possible to obtain a number of factors which are made use of subsequently in determining K, the coefficient of the viscosity of the blood. The factors involved in this calculation are the quantity of blood collected, during a definite period, the blood pressure, the specific gravity of the blood, and the length and internal diameter of the capillary-tube. The coefficients expressing the viscosity of the blood, are then compared with the coefficient of distilled water at 37° C., which, according to Poiseuille, possesses the value 4700. Hence, the viscosity of the blood is denoted in terms of multiples of the viscosity of distilled water at 37° C.

Only one capillary-tube was used in these experiments; its internal diameter measured 0.6636 mm. and its length 213.0 mm.

[1] This study was conducted under a grant from the Rockefeller Institute for Medical Research.

[2] Burton-Opitz, R., *Archiv für die ges. Physiol.*, 1900, lxxxii, 468.

[3] Hürthle, K., *Archiv für die ges. Physiol.*, 1900, lxxxii, 415.

The accuracy of the tube was tested by a series of preliminary experiments with distilled water.

The experiments were performed upon dogs during uniform light ether narcosis, no morphine having been administered beforehand. I tested the effect of warm and cold water baths and of hot dry air.

A.—THE EFFECT OF WARM AND COLD BATHS.

Six experiments in all were made, three with warm (43° C.) and three with cold water (23° C.). After securing the animal in a bath-tub, the normal viscosity of the blood was tested by three determinations at room temperature. The tub was then filled with warm or cold water. As the carotids were needed in experimentation, the ventral half of the neck and head were allowed to project above the surface of the water. Three other determinations of the viscosity were made fifteen, thirty, and forty-five minutes after the beginning of the bath.

The results of these experiments are compiled in Tables I and II; the first contains the experiments with warm, and the second, those with cold water. Each experiment is again subdivided into two parts, showing, on the one hand, the determinations of the normal viscosity, and, on the other, the determinations of the viscosity as influenced by the warm or cold bath. Among other details the tables also give the rectal temperature of the animal at the beginning and end of the experiment and the specific gravity of the blood. The latter factor was determined several times in the course of each experiment. Small pycnometers were used for this purpose.

These experiments prove conclusively that the viscosity of the blood reacts very sharply toward changes in the temperature of the surrounding medium. We observe that, in the case of the warm water, the coefficients become numerically larger than normal, while, in the case of the cold water, the coefficients become smaller. This implies that *the viscosity is decreased by warm and increased by cold water baths.* Let us take, for example, Experiment 2 of Table I. The viscosity of the blood ($K=862$) is in this case 5.4 times as great as that of distilled

TABLE I.

THE EFFECT OF WARM WATER BATHS.

Number of Experiment and Weight of Dog.		Determination Number.	Temperature °C. of water.	Temperature °C. of animal, rectal.	Time Elapsed since Beginning of Bath. Min.	Specific Gravity of the Blood.	Quantity Escaped from Capillary-Tube. Mgr.	Time. Sec.	Pressure Mm. Hg.	Viscosity Coefficient, K.	Mean Value of K.	Greatest Difference.
Exp. I. 11 kg.	Normal.....	1	—	37.2	—	1.05865	1688.3	13.04	168.60	796.71	788.47	74.43
		2	—	"	—	"	1789.7	14.43	163.40	787.50		
		3	—	37.0	—		1530.8	12.05	169.20	781.21		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	43.0	—	15	1.05802	1667.4	13.47	153.92	834.88	846.09	
		5	"	—	30	1.05690	2039.2	15.08	168.00	840.50		
		6	"	41.3	45	"	2417.3	14.96	194.60	862.90		
Exp. II. 11 kg.	Normal.....	1	—	37.4	—	1.05355	1594.9	11.48	164.40	881.00	862.81	119.98
		2	—	"	—	"	1687.3	12.44	165.60	853.87		
		3	—	37.1	—		1768.9	12.62	171.20	853.56		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	43.5	—	15	1.05260	1573.6	11.37	155.80	926.92	954.61	
		5	"	—	30	1.05202	1886.5	12.20	169.20	954.14		
		6	"	42.0	45	"	2346.5	14.90	167.30	982.79		
Exp. III. 8 kg.	Normal.....	1	—	37.5	—	1.0500	2004.2	13.28	151.90	1039.32	1038.09	101.39
		2	—	"	—	"	1782.1	11.89	149.60	1048.00		
		3	—	37.2	—		1663.1	12.32	137.50	1026.95		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	42.0	—	15	—	1782.9	10.39	159.60	1126.48	1134.11	
		5	"	—	30	1.04832	1768.9	10.78	151.30	1136.38		
		6	"	39.8	45	"	2038.7	12.26	152.90	1139.48		

TABLE II.

THE EFFECT OF COLD WATER BATHS.

Number of Experiment and Weight of Dog.		Determination Number.	Temperature °C. of water.	Temperature °C. of animal.	Time Elapsed since Beginning of Bath. Min.	Specific Gravity of Blood.	Quantity Escaped from Capillary-Tube. Mgr.	Time. Sec.	Pressure Mm. Hg.	Viscosity Coefficient, K.	Mean Value of K.	Greatest Difference.
Exp. I. 10 kg.	Normal.....	1	—	38.0	—	1.06290	1183.4	9.65	170.60	742.82	721.31	87.46
		2	—	"	—	"	1536.9	10.76	204.20	722.80		
		3	—	37.9	—		1592.4	12.19	193.30	698.33		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	22.5	—	15	1.06495	1761.3	13.77	198.00	666.27	647.53	
		5	"	—	30	1.06570	1907.5	15.33	199.60	642.49		
		6	"	32.4	45	"	2043.7	18.38	180.80	633.85		
Exp. II. 12 kg.	Normal.....	1	—	36.9	—	1.06030	1620.7	12.28	163.50	836.20	832.00	114.63
		2	—	"	—	"	2341.0	14.80	199.00	823.40		
		3	—	36.9	—		1860.3	13.69	168.30	836.40		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	23.0	—	15	1.06065	1859.0	16.08	157.50	760.10	741.72	
		5	"	—	30	1.06238	1806.1	14.76	169.20	747.70		
		6	"	33.0	45	"	2069.3	17.42	171.20	717.37		
Exp. III. 12 kg.	Normal.....	1	—	37.0	—	1.05236	1367.7	12.90	113.30	976.70	978.02	129.17
		2	—	"	—	"	1742.1	13.62	136.50	978.01		
		3	—	37.0	—		1871.7	13.92	143.30	979.36		
		....	.....	.....	.....	.....	.....	.....	.....	.....		
	During Bath	4	22.0	—	15	1.05375	1761.9	14.20	135.60	953.80	898.32	
		5	"	—	30	"	2025.7	17.17	136.00	904.22		
		6	"	—	45	"	2382.6	17.61	159.10	886.41		
		7	"	33.5	60	"	1198.3	11.17	131.70	848.85		

water at 37° C. (K=4700). Under the influence of the warm water bath, the viscosity was reduced in the course of forty-five minutes (K=982) to only 4.7 times as great as that of distilled water at 37° C. Equally pronounced effects were obtained with cold water. In Experiment 3, Table II, the viscosity of the blood was increased in the course of forty-five minutes from 4.8 to 5.5 times as great as that of distilled water at 37° C. Moreover, when a comparison is made between the time and the total increase or decrease in the viscosity, it is seen that by far the greatest change takes place during the first ten to fifteen minutes after the beginning of the bath.

The specific gravity of the blood pursued in these experiments a course parallel to the viscosity. Warm water baths produced a decrease and cold water baths an increase in the specific gravity. The changes were very pronounced in both cases.

B.—THE EFFECT OF HOT AIR BATHS.

The method followed in the three experiments of this group was similar to that described in an earlier paragraph of this paper. The animal was placed in a glass case, through which a constant stream of dry hot air could be passed. As the carotids were used in experimentation, it was necessary to keep the head and neck of the animal outside of the case. As in the preceding six experiments, the animal was allowed to pant freely.

The normal viscosity of the blood having been determined several times, the temperature of the air in the case was gradually raised to about 60° C. Three determinations were then made, fifteen, thirty, and forty-five minutes afterward.

The results of the experiments are given in Table III. Each experiment is divided into two parts, showing the viscosity of the blood before, as well as during the air bath. The table also contains the temperature of the animal at different periods of the experiment, the temperature of the air, and the specific gravity of the blood.

A comparison of the coefficients proves that hot air baths do not render the blood less viscous, as one might suppose, but more

TABLE III.

EFFECT OF HOT AIR BATH.

Number of Experiment and Weight of Dog.		Determination Number.	Temperature ° C. of air.	Temperature ° C. of animal.	Time Elapsed since Beginning of Bath. Min.	Specific Gravity of Blood.	Quantity Escaped from Capillary-Tube. Mgr.	Time. Sec.	Pressure. Mm. Hg.	Viscosity Coefficient, K.	Mean Value of K.	Greatest Difference.
Exp. I. 9 kg.	Normal.....	1	—	37.2	—	1.06118	1475.3	12.17	160.70	780.80	769.07	22.07
		2	—	"	—	"	1492.2	12.87	156.70	765.85		
		3	—	37.1	—	"	1588.3	13.22	163.50	760.58		
		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	During Bath	4	65.0	—	15	1.06222	1448.2	12.67	155.80	758.58	751.74	
		5	"	—	30	"	1335.7	12.61	146.10	749.66		
		6	"	41.0	45	1.06480	1119.5	11.40	135.60	747.00		
Exp. II. 10 kg.	Normal.....	1	—	37.0	—	1.05338	1466.3	12.63	127.90	946.46	930.51	42.41
		2	—	"	—	"	1481.7	13.64	123.00	920.88		
		3	—	36.8	—	"	1574.9	13.28	133.80	924.19		
		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	During Bath	4	70.0	—	15	1.05520	1626.5	12.26	153.70	898.45	891.85	
		5	"	—	30	"	1530.8	13.15	137.30	889.00		
		6	"	42.2	45	"	1053.6	12.77	96.70	888.10		
Exp. III. 9 kg.	Normal.....	1	—	37.2	—	1.05435	2017.6	14.28	152.90	962.64	975.44	54.89
		2	—	"	—	"	1950.5	14.71	142.00	972.75		
		3	—	37.0	—	"	2293.7	13.17	183.10	990.95		
		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	During Bath	4	60.0	—	15	1.05500	2056.2	13.27	171.10	942.81	931.72	
		5	"	—	30	"	1802.6	13.61	148.00	931.81		
		6	"	40.5	45	"	1811.5	14.53	141.00	920.55		

so. Hence, the hot air and warm water produce directly antagonistic results. It seems, however, that the former is less powerful, because the increase in the viscosity produced by a constant exposure of the body to air of about 60° C. did not amount to more than fifty-five points in any of the experiments. For example, in Experiment 3, of Table III, the normal viscosity was 4.8 times as great as that of distilled water at 37° C. Under the influence of the hot air it became, in the course of forty-five minutes, 5.1 times as great. We will remember that the differences obtained with warm and cold water were much more marked and rapid.

The specific gravity of the blood became greater during the hot air bath. The viscosity and specific gravity preserved, therefore, a direct relationship with one another.

The coefficients for the normal blood of the dog vary in the present nine experiments between 1038 and 721, the average being 877. The viscosity of the dog's blood is therefore 5.3 times as great as that of distilled water at 37° C.