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Some aspects of the blood and tissue
chemistry of the foetal calf. 1928.

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SOME ASPECTS OF THE BLOOD AND TISSUE CHEMISTRY
OF THE FOETAL CALF.

The chemistry of the blood and tissues of embryos has not been very extensively studied. Most of the work reported has been carried out on the human foetus and in this case one must of necessity use blood which has been taken at birth. It was thought that a more detailed study could be made by using calf foetuses as they can be obtained at all stages of development.

For this piece of work foetal calves were obtained from the abattoir during the slaughter of adult female cattle. The removal of the uterus would take place about fifteen minutes after death. Because of this, asphyxia developed in the foetus before the blood could be obtained. This factor caused considerable change in some of the chemical constituents of the blood as shown by Collip²⁷.

The foetuses examined ranged in length from three to one hundred and twenty-two centimeters. Observations were made on the following constituents of blood, spinal fluid, and amniotic fluid:- calcium of serum, spinal fluid, and amniotic fluid; inorganic and acid soluble phosphorus of whole blood, serum, spinal fluid, and amniotic fluid; urea nitrogen and non-protein nitrogen of whole blood, serum, spinal fluid, and amniotic fluid; amino-acid nitrogen of whole blood; creatinine, creatine, uric acid, and cholesterol of whole blood; chlorides of whole blood, serum, spinal fluid, and amniotic fluid; serum albumin and serum globulin; sugar of whole blood and spinal fluid; carbon dioxide combining power and hydrogen ion concentration of serum. Tissue analyses were carried out for gly-

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cogen and water content.

A few determinations were also made on the whole blood and serum of cows for comparative purposes.

Review of the Literature,-

Bogert and Plass¹ found the average value for foetal serum calcium at birth was somewhat higher than that of the mother, and that the maternal serum calcium was slightly lower than the normal for non-pregnant women. The magnesium content was the same in both foetal and maternal serum.

Hellmuth² has found that foetal serum always contains more calcium than maternal serum.

Plass and Tompkins³ determined the distribution of phosphoric acid compounds in the serum of the mother and foetus. Lipoid phosphorus was found to increase above the value for normal women, at the time of delivery, and practically no lipoid phosphorus was present in the foetal serum. Inorganic and organic phosphorus were higher in the foetus, probably to give the optimum conditions for bone formation.

Hess and Matzner⁴ found the inorganic phosphorus of foetal blood to be consistently higher than that of the mother, but they found very little if any difference between the maternal and foetal sera.

K. von Oettingen⁵ has demonstrated a higher concentration of chlorides, inorganic phosphorus, sodium, potassium, and amino-acids in foetal blood than in that from the mother. He has also found creatinine to be the same in both.

Mendeleeff⁶ found that the rate of cellular growth of embryonic guinea pig tissue cultures depends on the reaction of the medium, and that proliferation increased with decreasing P_H .

Slemons and Morriss⁷ carried out non-protein nitrogen and urea determinations on the blood of foetuses at birth and on blood taken from the mother at the same time. They found that in normal cases the values were practically the same in both mother and foetus. An increase in the maternal urea due to any of the toxæmias of pregnancy gave a corresponding increase in the foetal blood urea. Administration of chloroform during pregnancy gave an increase primarily in the foetal urea and, if prolonged, also in the maternal urea. Asphyxia caused an increase in the urea content of foetal blood.

Howe and Givens⁸ studied the non-protein nitrogen and urea nitrogen of foetal and maternal blood. They found no consistent difference. In many cases they were the same in both mother and foetus. Uric acid was found to be slightly increased in parturient women. Sugar also increased due to the anaesthetic and muscular contractions.

Morse⁹ stated that the amino-acids in the blood remained normal during pregnancy, pre-eclamptic toxæmia, eclampsia, and nephritic toxæmia, but slight rises were encountered in some cases of obscure toxæmia, possibly related to acute yellow atrophy of the liver. The average value for the amino-acid nitrogen of foetal blood was slightly higher than that of the mother.

Plass and Matthew¹⁰ found that amino-acids and non-protein nitrogen were consistently higher in foetal serum and whole blood than in that of the mother. Many previous investigators

had not found this to be true and had concluded simple diffusion of these substances took place through the placenta. Urea and uric acid were found to be the same on either side of the placenta.

Plass¹¹ carried out analyses for creatinine and creatine on samples of blood taken simultaneously from mother and foetus at the time of delivery. The determinations were made on serum or plasma as these are really the fluids concerned with placental interchange. Creatinine and creatin were the same in the plasmas of both mother and foetus and they were the same as those found in non-pregnant women.

Hunter and Campbell¹² stated that the creatinine and creatine were the same in maternal plasma as in the foetal. A slight rise of creatinine was found during parturition in primiparous women. The creatin content of foetal whole blood was slightly higher than maternal even though the concentration in corpuscles and plasma is the same in both. Pregnancy seemed to cause the storing of creatine in the corpuscles.

Kingsbury and Sedgwick¹³ have shown that at the time of birth uric acid was the same on both sides of the placenta. There was an increase during the first few days after birth and then a decrease by the fifth day.

Slemons and Bogert¹⁴ have reported that uric acid of the blood remains normal during uncomplicated pregnancy but it may increase to quite a great extent in cases of syphilis, nephritis, eclampsia, and other toxæmias of pregnancy, and there may even be a slight increase during a normal labour in primiparous women.

Slemons and Curtis¹⁵ have found that the cholesterol con-

tent of foetal and maternal blood was practically the same at the end of gestation. They found a hypercholesterolemia beginning about the fifth month when the metabolism of fats became active in the foetus.

Slemons and Stander¹⁶ found the fat content of maternal blood to be much higher and seemingly independent of the foetal blood. On account of this lecithin and cholesterol were found in larger quantities in maternal blood. The greater part of the cholesterol present in foetal blood was found to be free. No significant change was found in lipoids during eclampsia or other toxæmias of pregnancy.

Plase and Matthew¹⁷ have found that the total protein, the albumin, globulin and fibrin were uniformly higher in maternal than in foetal blood. In the case of pregnancy it was found that the albumin decreased and the fibrin increased.

Morris¹⁸ found that the values for blood sugar remained normal during pregnancy and the first stage of labour, but there was a slight increase during the second stage due to muscular contractions and it was accentuated by an anaesthetic. In the case of normal foetuses the blood sugar at the moment of delivery was slightly lower than in the maternal circulation.

Aron¹⁹ determined the sugar content of the blood of guinea pig embryos of various sizes. He found a very great difference between that and the sugar content of the mother's blood until near full term. He also did a few determinations on foetal calf blood and found them lower than that of the mother but with not so great a difference as that existing in the case of the guinea pig.

Rowley²⁰ reported the fact that the blood sugar on the foetal side of the placenta at birth was lower than that on the maternal side. He also stated that muscular contractions did not affect the level of the blood sugar, differing in this respect from the findings of Morriss¹⁸.

Burgess²¹ carried out blood sugar determinations on the blood from mother and foetus. In four out of six cases the sugar was slightly higher in the maternal blood.

Hellmuth²² reported that foetal blood sugar is always lower at birth than that of the mother, but is dependent on it.

Gogoberidize²³ carried out glycogen determinations on rabbit foetuses and on various organs of the mother. The glycogen content of the embryo increased to the twenty-eighth day after which there was a decrease. The muscles contained the most glycogen. The glycogen of the placenta and uterus increased for a time during pregnancy during which time the maternal liver glycogen decreased. At parturition the placenta was practically glycogen free while the muscles of the uterus had a high glycogen content.

Clogne, Welti, and Pichon²⁴ found the amount of glycogen present in the foetal liver increased from 1.8 gm. in the third month of pregnancy to 29.5 gm. in the ninth month. During the same time the glycogen in the placenta decreased from 2.7 gm. to 0.6 gm. at full term.

Mendel and Leavenworth²⁵ found that in the case of the pig embryo the glycogen content of the muscle increased with the age of the foetus and that it reached a value over one per cent at full term. They also found that the liver did not assume its

glycogen storing function early in embryonic life.

Stander and Tyler²⁶ have found that That the moisture content of maternal blood increased to the seventh month of pregnancy after which it remained constant or decreased slightly. The moisture of the whole blood was higher in the mother than the foetus. The ash of the maternal and foetal plasma was exactly the same, thus indicating the free exchange of inorganic substances through the placenta.

Methods.-

The following methods were used in the chemical analyses.

1. Calcium	- Clark-Collip modification of the Kramer-Tisdell method.
2. Phosphorus	- Method of Fiske and Subbarow.
3. Urea nitrogen	- Urease method of hydrolysis and distillation apparatus used in Clark-Collip urea method.
4. Non-protein-nitrogen	- A micro-Kjeldahl method using 1/2 gm potassium sulphate, 5 drops 5% copper sulphate, and 1 c.c. concentrated sulphuric acid in the digestion and the distillation apparatus mentioned above.
5. Amino-acid-nitrogen	- Folin method using B-naphthaquinone.
6. Creatinine	- Picric acid method of Folin.
7. Creatin	- Hydrolysed in an autoclave and then determined as creatinine.
8. Uric acid	- Brown direct method.
9. Cholesterol	- Modified method of Myers and Wardell
Cholesterol was extracted with chloroform and determined colorimetrically by using acetic anhydride and sulphuric acid.
10. Chlorides	- Volhard method.
11. Serum proteins	- A micro-Kjeldahl as described under non-protein nitrogen above.

Total nitrogen was determined and on another portion of the specimen the albumin was determined after precipitating the globulin with 22.2% sodium sulphate.

12. Sugar

- Micro-Shaffer-Hartman method.

13. Glycogen

- Pfluger's method of extraction after which sugar was determined by the Shaffer-Hartman method.

14. Carbon-dioxide capacity of the plasma -

Van Slyke and Cullen method.

15. H-ion.

-Potentiometer.

TABIE 11.

Inorganic and Acid Soluble Phosphorus in mg. per 100 c.c.

No. and length
of specimens

Whole blood

Serum

Spinal fluid

Amniotic Fluid

Foetus

Inor. Acid Sol.

Inor. Acid Sol.

Inor. Acid Sol.

Inorg. Acid Sol

1-4 cms

1-4 "

1-9 "

1-14 "

1-15 "

1-17 "

1-18 "

1-19 "

2-22 "

1-23 "

1-24 "

1-26 "

1-26 "

1-27 "

2-28 "

1-29 "

4-31 "

1-31 "

1-31 "

1-33 "

1-34 "

3-36 "

2-38 "

1-39 "

1-41 "

4-43 "

3-46 "

1-48 "

1-50 "

1-51 "

3-51 "

1-53 "

3-53 "

2-56 "

1-58 "

2-61 "

3-64 "

1-66 "

1-66 "

1-69 "

1-69 "

1-71 "

1-71 "

1-74 "

1-74 "

1-79 "

2-79 "

1-81 "

1-84 "

19.2

38.1

10.9

30.4

10.0

21.6

15.1

31.5

12.2

31.7

11.4

29.2

8.4

23.9

15.4

33.8

11.7

14.0

11.4

27.1

9.4

22.4

15.7

29.2

11.8

27.5

13.1

32.1

15.4

29.4

11.9

30.5

10.9

24.7

12.9

28.1

8.7

16.4

11.7

26.4

12.3

25.6

13.9

28.1

11.2

24.8

14.0

27.4

11.2

27.1

10.3

24.2

11.6

24.6

9.6

21.6

15.5

31.4

15.2

16.2

7.0

7.8

10.2

20.2

9.8

22.4

10.4

21.2

9.8

23.1

11.8

27.5

11.6

24.3

12.8

11.4

7.1

9.4

10.6

21.6

7.0

21.6

5.2

6.7

10.1

23.6

8.7

18.8

9.1

23.5

3.9 4.6

5.2 7.2

4.8 5.2

5.2 6.3

1.5 4.1

1.4 3.8

1.6 2.8

1.9 3.1

2.5 4.3

3.0 3.5

1.5 4.1

3.2 4.1

2.6 2.9

3.5 3.6

4.4 5.6

1.7 4.3

TABLE 2 (Continued)

1-86 cms	11.7	24.6						1.6	2.8
2-86 "	9.7	19.2							
1-89 "	9.8	23.6	10.0	12.1	4.2	4.9			
1-89 "	11.4	26.4							
1-94 "	9.8	21.8	9.8	10.3	4.7	5.2		3.6	4.2
1-94 "	10.0	18.8							
1-99 "	9.1	17.6							
1-107 "	10.7	24.8	11.3	13.2	4.2	6.1			
1-107 "	9.7	15.4							
	Av.=	Av.=	Av.-	Av.-	Av.-	Av.-		Av.-	Av.-
	11.5	25.2	11.4	12.8	5.4	6.6		2.9	4.2
Calf									
1-2 hrs old	5.2								
1-3 " "	6.2	19.2			2.2	2.7			
1-2 days "	5.4								
1-8 " "	6.4								
1-10 " "	9.4	23.2			2.0	2.1			
1-10 mos "	7.3								
Cow									
6	3.9	20.6							
4			5.4	7.8					

TABLE 111.

Urea N and Non-Protein Nitrogen in mg. per 100 c.c.

Age and length of specimens	Whole Blood		Serum		Spinal Fluid		Amniotic Fluid	
	Urea N	NPN	Urea N	NPN	Urea N	NPN	Urea N	NPN
-4 cms							2.7	8.2
-8 "							3.6	8.6
-13 "							3.8	7.9
-15 "							5.8	11.2
-18 "	17.6						8.1	15.8
-18 "							6.3	12.4
-20 "		53.3						
-23 "	12.6	49.3					8.1	11.8
-23 "		56.3						
-26 "	11.7	51.5					4.5	11.6
-28 "		51.1						
-28 "	14.7	44.9						
-31 "	14.1	42.3						
-31 "							10.2	16.1
-33 "	10.1							
-33 "							8.8	15.7
-33 "	15.1	45.1						
-33 "	42.0	57.5	32.5	53.3				
-36 "	13.4	38.3						
-38 "	13.3	53.9						
-38 "		37.0						
-41 "	15.5	60.2						
-41 "							3.8	14.3
-43 "	15.9	48.7						
-46 "	13.3	48.4						
-46 "		37.5						
-46 "	25.8	50.1	22.3	47.6				
-48 "	20.2	39.8						
-51 "	17.1	46.4						
-51 "	17.3	45.7					22.1	28.2
-53 "	17.7	57.0						
-53 "		44.6				22.1	21.8	
-56 "	26.0	53.3	22.0	46.2				
-58 "	14.3	40.6						
-61 "	14.3	54.3						
-64 "	13.4	57.7						
-64 "		45.4						
-66 "		60.2	11.3	41.2	10.1	18.2		
-66 "	10.4						9.5	22.7
-66 "	14.8			40.1				
-69 "	18.2	40.1						
-69 "	25.8	49.2	22.4	38.8				
-71 "	16.2	42.1	14.2	36.2	11.4	19.4	21.6	25.8
-71 "	13.1	47.3						
-74 "	19.6	60.2	16.2	46.1	19.5	21.8	23.8	
-74 "	13.7	42.0		34.5				
-74 "	15.4	40.9						
-79 "	15.3	53.7						
-84 "	10.4	53.2						
-86 "		46.0	16.5	39.2				
-86 "	11.2	44.9						

 	

TABLE IV.

Amino-acid Nitrogen in mg. Per 100 c.c.

<u>No. and length of Specimens</u>		<u>Amino-Acid N.</u>
Foetus		
1-24	cms	12.7
1-28	"	14.7
1-31	"	12.1
2-33	"	11.6
2-38	"	10.5
1-41	"	11.8
3-46	"	14.0
3-51	"	14.4
2-53	"	11.7
1-64	"	13.0
2-66	"	13.7
1-69	"	12.5
1-71	"	13.6
2-74	"	11.6
2-86	"	10.7
1-92	"	11.8
1-101	"	10.0
1-107	"	9.6
1-112	"	10.7
Av. =		13.1
Cow	12	6.8

TABLE V.

Creatinine, Creatin, Uric Acid, and Cholesterol in Foetal Blood
Expressed in mg. per 100 c.c. of blood.

No. and length of specimens	Creatinine	Creatin	Uric Acid	Cholesterol
Foetus				
1-20 cms	1.2	6.5		
3-28 "	1.5	5.5		
2-31 "	1.3	5.8		
1-33 "	1.2	4.8		
1-36 "	1.2	5.7		
1-43 "	1.4	5.3		
3-46 "	1.3	5.4		
1-48 "	1.2	6.1		
1-51 "	1.5	6.8		
1-58 "	1.7	5.4		
1-69 "	1.7	6.4		
1-86 "	1.6	5.3		
2-89 "	2.2	5.4		
1-94 "	2.0	4.9		
	Av.=1.5	Av.6.1		
1-23 "			3.2	21.9
1-26 "				38.1
1-28 "				46.7
1-33 "			3.5	32.9
3-38 "				37.0
1-41 "				37.0
1-43 "				50.0
2-46 "				39.7
1-51 "			4.1	32.6
2-53 "				33.7
1-61 "				43.2
1-64 "			3.8	59.2
1-71 "				33.9
2-79 "				49.8
1-84 "			3.4	37.2
			Av. 3.6	Av.39.5
Cow				
3	1.6	5.9	3.8	

TABLE VI.

Chlorides in mg. per 100 c.c.

No. and length of specimens	Whole Blood	Serum	Spinal Fluid	Amniotic Fluid
Foetus				
1-4 cms				220
1-8 "				630
1-13 "				280
1-15 "				640
1-18 "				650
1-20 "				650
1-23 "	470			680
1-26 "				
1-28 "	470			
1-31 "		540		680
1-33 "	470			660
2-38 "	480			
1-41 "				670
2-46 "	455			
1-46 "	450	530		
1-51 "	480			620
1-51 "	460			
1-53 "	500	540		
1-53 "		480	600	
1-53 "	510			
1-64 "	460			
1-66 "	490		670	
1-69 "	490			
1-71 "	470	510	620	610
1-74 "	460	500	650	170
1-74 "	480			
2-86 "	485			
1-92 "	480			
1-107 "	480	520	660	110
1-112 "	460			
		Av.=514	Av 640	Av. 520
	Av.=475			
Calf				
1-10 mos. old	460			
Cow				
6	440	482		

TABLE VII.

Serum Proteins in mg. per 100 c.c. serum

No and length of specimens	Total Nitrogen	Albumin Nitrogen
Foetus		
1-36 cms	500	310
1-41 "	540	410
1-46 "	520	370
1-51 "	570	320
1-66 "	610	380
1-71 "	580	310
1-79 "	590	280
1-86 "	620	510
1-109 "	690	420
1-117 "	720	400
1-122 "	700	510
	Av. = 604	Av. = 393
Calf		
1-3 hrs. old	920	470
1-2 days "	890	490
1-10 " "	940	510
Cow		
1	1210	590
1	1190	570
1	1140	610
1	1380	580
1	1160	490
1	940	480
	Av. = 1170	Av. = 553

TABLE VIII.

Sugar in Foetal Blood and Spinal Fluid.

No. and length of specimens		Spinal Fluid sugar	Blood Sugar
Foetus			
1-53	cms	0.028 %	
2-66	"	0.038	
1-74	"	0.018	
1-89	"	0.043	
1-92	"	0.021	
1-94	"	0.028	
2-97	"	0.006	
1-109	"	0.002	
1-117	"	0.008	
		Av. = 0.021	
1-36	"		0.272%
1-66	"		0.147
1-79	"		0.190
1-122	"		0.368
			Av. = 0.244

TABLE 1X

Foetal Tissue Glycogen.

No. and length of specimens	Skeletal muscle	No. Specimens	Heart Muscle
Foetus.			
1-15 cms	1.02%	2-28 cms	1.63%
1-18 "	1.18	1-33 "	2.08
1-20 "	1.61	1-43 "	1.06
1-23 "	1.74	1-46 "	1.12
1-26 "	1.41	1-53 "	1.02
2-28 "	1.41	1-58 "	1.13
1-31 "	2.18	1-69 "	0.73
2-33 "	1.24	1-71 "	1.30
1-36 "	1.24	1-84 "	0.74
1-41 "	1.33	1-94 "	0.80
1-43 "	1.42		
2-46 "	1.38		Av.=1.20
1-48 "	1.54		
2-51 "	1.69		
1-53 "	2.32		
1-58 "	1.59		
1-61 "	1.63		
1-69 "	3.13		
1-71 "	2.80		
1-79 "	2.91		
1-84 "	3.26		
1-94 "	3.44		
1-107 "	2.38		
	Av.=1.83		
Calf.			
1-2 hrs old.	1.34	1-2 hrs old	0.46
1-3 days "	1.02	1-3 days "	0.17
1-4 " "	1.11	1-4 " "	0.17
1-10 " "	1.48		

No. and length
of specimens

[illegible]

TABLE XI.

Carbon Dioxide Combining Power and P_H .

No. and length of specimens	P_H	CO_2 combining power.
Foetus		
1-31 cms	6.83	
1-33 "	6.90	
1-41 "	6.79	
1-51 "	6.91	
1-66 "	7.05	
1-117 "	6.99	
	Av = 6.91	
Adult cow		
6	7.33	
Foetus		
1-31 cms		29.9
1-46 "		33.5
1-53 "		34.4
1-53 "		28.1
1-66 "		22.2
1-74 "		35.3
1-107 "		44.0
		Av. = 32.5
Adult cow		
5		62.4

Discussion of Results:

The calcium and phosphorus content of foetal calf blood was found to be much higher than expected. At birth a normal foetus has a calcium content slightly higher than the normal average for adults. This may be seen in Table 1. where the calcium values for calves two and three hours and even two days old, range from one to two milligrams higher than for the adults. This fact was reported by Bogert and Plass ¹ when studying the human foetus. However the calcium for the foetal calf serum averaged about four milligrams higher than cow's serum.

The inorganic and acid soluble phosphorus values were much higher in the case of the foetus, whereas one might expect only slightly higher values than those for the mother. Plass and Tompkins ³ found that the acid soluble and inorganic phosphorus were higher in the foetus but the total phosphorus was higher in the mother due to the much larger amount of lipoid phosphorus. It was found that asphyxia caused the abnormally high values for calcium and phosphorus in the foetal calf serum.

As shown by Collip ²⁷ there is a decrease in blood volume with asphyxia and as there is practically no calcium in the cells this might account for the increase in calcium, otherwise there must be an actual mobilization of calcium and phosphorus from some source in the body. The former does not seem so probable because in the case of the calf foetus there cannot be much decrease in blood volume because the average for ten cases gave only twenty-eight percent cells while the average for the blood of ten cows gave forty-two percent cells.

There is also a decrease in P_H in the foetal blood, caused by asphyxia. When taken for a large number, the P_H of foetal calf bloods averaged 0.42 lower than for the adult. The carbon dioxide combining power was also less due to the acidosis. Blair Bell²⁸ and his co-workers reported that the P_H was lower and the lactic acid content higher in human foetal blood than in that from the mother. The blood was drawn from the umbilical vessels, and it seems quite possible that there may have been enough asphyxia of the blood to give these changes, as he finds that in cases of Caesarean operation the difference is not so great. He also found the lower alkali reserve.

During the course of this work, an experiment was carried out on a female dog carrying foetuses of almost full term. After being anaesthetized, an operation was performed to expose the uterus. Blood was drawn directly from the foetuses contained in one arm of the uterus. The other arm was ligated and the foetuses asphyxiated for twenty minutes, after which blood was drawn from each.

The average values for the determinations carried out were as follows:-

Normal foetuses.			
Calcium	-	11.5	mg./100 c.c.
Inorg. phosphorus	-	7.3	" "
Asphyxiated foetuses.			
Calcium	-	13.0	" "
Inorganic phosph.	-	11.0	" "
Mother.			
Calcium	-	9.2	" "
Inorg. phosphorus	-	5.2	" "

The average value for the cholesterol content of the foetal blood was about 30 mg./100c.c. less than that of the mother.

This experiment would lead one to believe that the calcium and inorganic phosphorus of the normal dog foetus is higher than that

of the mother and that this difference is accentuated by asphyxia.

The average calcium content of the cerebral spinal fluid of the foetal calf was about one half that of serum. In the case of amniotic fluid the calcium values varied over a great range. It was thought that this variation might in some way be related to the degree of calcification of the placenta, so more were done, but it was found that even in these cases the calcium values varied greatly.

The inorganic and acid soluble phosphorus were nearer the same in the spinal and amniotic fluids than in blood, thus showing that less organic phosphorus is present. This is also true of serum.

The Fiske and Subbarow, and Briggs methods were compared when doing inorganic phosphorus determinations. Almost identical results were obtained.

Non-protein nitrogen was consistently higher in foetal blood than in that of the adult, although the average values for urea of whole blood were almost the same in both. Most of the difference can be accounted for from the fact that amino-acids exist in much larger quantities in the foetal blood. The average was practically twice that of the adult. As amino-acids are important in building the foetal organism, it seems to show a selective absorption of some sort on the part of the placenta or excessive manufacture of amino-acids in the foetus.

Urea nitrogen did not vary much between whole blood, serum, spinal fluid and amniotic fluid. Plass and Matthew¹⁰ have reported higher values of amino-acids and non-protein nitrogen in the human foetus than in the mother. Morse⁹ and K. von Oettingen⁵

have also found the amino-acid content of foetal blood slightly higher than maternal blood.

That asphyxia causes an increase in blood urea is claimed by Slemons and Morriss⁷. This does not seem to take place in the foetal calf as the values for urea were no higher than in the blood of the adult.

There seemed to be nothing unusual about the creatinine, creatine, or uric acid determinations on foetal blood.

Plass and Matthew¹⁰, Slemons and Bogert¹⁴, and also Kingsbury and Sedgwick¹³ have found that uric acid was generally the same on either side of the placenta. Creatine and creatinine have also been reported by Plass¹¹ to be quite diffusible and to exist in the same concentrations in foetal and maternal plasma, this being also reported by Hunter and Campbell¹².

Little comment can be made on the chloride determinations, except the fact that slightly higher concentrations were found in foetal than in cow's blood. The values for chlorides in spinal fluid and serum were slightly higher than for whole blood and this is a normal occurrence. Several very low values were obtained for chlorides in amniotic fluid. These were checked by the Van Slyke method of analysis and found to be the same. K. von Oettingen⁵ found that chlorides were always higher in foetal than in maternal blood.

Serum proteins were lower in foetal serum than in cow's serum. The values for both albumin and total nitrogen were consistently lower. Plass and Matthew¹⁷ found this to be true in the case of human foetal serum.

The sugar content was lower than would be expected in spinal fluid, especially considering the fact that the blood sugar was increased above normal due to asphyxia. Hellmuth²² and Burgess²¹

found lower sugar values in normal human foetal blood at birth than in the mother. Aron¹⁹ stated that the blood in the guinea pig embryo has a very much lower sugar content than the mother until near full term. This fact could not be studied by dealing with the blood of foetal calves as there was an abnormal sugar value due to asphyxia.

The glycogen content of foetal calf skeletal muscle was high and increased with the size of the foetus, while that of heart muscle was lower and tended to decrease with an increase in the size of the foetus.

Gogoberidze²³ has reported that in the rabbit embryo muscle has a higher glycogen content than any other tissue. This was found by Mendel and Leavenworth²⁵ to be also true in the case of the pig embryo.

Cholesterol was found to be extremely low in the foetal blood. Slemons and Stander¹⁶ have shown this to be true also in the case of the human foetus. They found that the cholesterol occurring in foetal blood is nearly all in the free condition, as esterified cholesterol goes to make up the lipoids of the blood and this constituent is much lower on the foetal side of the placenta.

The water content of foetal tissues is very high as compared with the average for adult cattle. It may be seen from Table X that the water content of muscle, kidney, and brain decreases with increasing age of the foetus. The remaining tissues do not show such a consistent relation. Stander and Tyler²⁶ have found the moisture content of human foetal blood less than that of the mother. This is not indicated in the case of the foetal calf even in the foetuses of almost full term. Here, too, there has been the possibility of a concentration of blood volume due to asphyxia. Stander

and Tyler²⁶ also made the statement that because the ash of foetal and maternal serum was the same that free exchange of inorganic substances through the placenta was indicated. In the opinion of the writer this is not necessarily true. The individual inorganic constituents might be quite different in the blood of the mother and foetus and the total ash be the same. Taking the case of calcium and phosphorus for example; the serum calcium for a normal foetus or new-born individual is higher than that of the mother and the total phosphorus is lower due to the deficiency of lipid phosphorus in foetal blood and serum.

A summary of all the quantitative determinations is included in the following table.

Summary Material	Constituent	No. Determinations	Average Value	
Foetus				
Serum	Calcium	99	14.8 mgs/100 c.c.	
Spinal Fluid	"	23	7.1 "	"
Amniotic Fluid	"	36	8.7 "	"
Whole blood	Ing. Phosphorous	72	11.5 "	"
Serum	" "	5	11.4 "	"
Spinal Fluid	" "	8	5.4 "	"
Amniotic Fluid	" "	18	2.9 "	"
Whole Blood	Acid Sol."	71	25.2 "	"
Serum	" "	5	12.8 "	"
Spinal Fluid	" "	8	6.6 "	"
Amniotic Fluid	" "	18	4.2 "	"
Whole blood	Urea N.	62	16.7 "	"
Serum	" "	10	19.3 "	"
Spinal Fluid	" "	4	15.3 "	"
Amniotic Fluid	" "	22	12.1 "	"
Whole blood	N.P.N.	75	48.1 "	"
Serum	" "	12	41.4 "	"
Spinal Fluid	" "	5	20.4 "	"
Amniotic Fluid	" "	19	15.0 "	"
Whole blood	Amino-Acid N	29	13.1 "	"
Whole blood	Creatinine	20	1.5 "	"
Whole blood	Créatin	20	6.1 "	"
Whole blood	Uric acid	5	3.6 "	"
Whole Blood	Cholesterol	20	39.5 "	"
Whole blood	Chlorides	23	475 "	"
Serum	"	7	514 "	"
Spinal Fluid	"	5	640 "	"
Amniotic fluid	"	14	520 "	"
Serum	Total N	11	604 "	"
Serum	Albumin N	11	393 "	"
Spinal fluid	Sugar	14	0.021% "	"
Whole blood	"	4	0.244%	
Skeletal Muscle	Glycogen	27	1.83%	
Heart Muscle	"	11	1.20%	

Summary (Continued)

Foetus

Liver	Solid content	5	19.4%
Spleen	" "	5	18.3%
Kidney	" "	5	14.2
Lung	" "	5	12.2
Heart	" "	5	15.5
Muscle	" "	5	17.0
Brain	" "	4	12.2
Blood	" "	4	14.9
Serum	PH	6	6.91
Serum	CO ₂ Comb Power	7	32.5

Cow

Serum	Calcium	7	10.5 mgs/100 cc
Whole blood	Inorg. Phosphorus	6	3.9 " "
Serum	" "	4	5.4 " "
Whole blood	Acid Sol "	6	20.6 " "
Serum	" " "	4	7.8 " "
Whole blood	Urea N.	10	17.9 "
Serum	" "	9	14.5 " "
Whole blood	N.P.N.	11	36.2 " "
Serum	" "	9	28.1 " "
Whole blood	Amino-Acid N.	12	6.8 " "
Whole blood	Creatinine	3	1.6 " "
Whole blood	Creatin	3	5.9 " "
Whole blood	Uric Acid	3	3.8 " "
Whole blood	Chlorides	6	440 " "
Serum	"	6	482 " "
Serum	Total N.	6	1170 "
Serum	Albumin N.	6	553 "
Whole blood	Solid content	4	20.9%
Serum	PH	6	7.33
Serum	CO ₂ Comb power	5	62.4

The abnormally high values for calcium of foetal serum and the inorganic and acid soluble phosphorus of foetal whole blood and serum were due to asphyxia. The increased hydrogen ion concentration and high values for sugar were due to the same cause.

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