EXPERIMENTAL RICKETS IN RATS.

VII. The Prevention of Rickets by Sunlight, by the Rays of the Mercury Vapor Lamp, and by the Carbon Arc Lamp.

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It is now well established that infantile rickets can be prevented or cured by means of sunlight, or light from various artificial sources. Recently it has been shown by Hess, Unger, and Pappenheimer (1), and by Powers, Park, Shipley, McCollum, and Simmonds (2), that light is able to exert a similar favorable influence on the experimental rickets of rats. For the past year a large series of experiments, some of which have been reported in abstract as the work progressed, has been carried out in this laboratory with sunlight and rays of different kinds under a great variety of conditions. The investigation has included a study of the effect of variation of intensity, of transmission, or of reflection of light, of duration of exposure, of temperature, of the diet of the experimental animals, and the pigmentation of the skin, as well as other factors. A summary of the results of many of these experiments is incorporated in Tables I to VIII.

The Effect of Sunlight.

For all experiments young rats about 40 to 50 gm. in weight were used. They were kept in a darkened room at all times. After an interval of about 21 days they were radiographed for the appearance of rickets at the epiphyses of the knee joints, and were killed after a total period of 25 to 28 days. In almost every instance the bones

TABLE 1.

Protective Experiments with Sunlight.

Rat No.	Diet.	Weight.		Sunlight exposure.		Rickets.		
		Initial.	Final.	Length of time daily.	Total.	Radiogram.	Pathological examination.	
							Gross.	Microscopic.
		gm.	*gm.*		*hrs.*			
246	No. 84	30	32	None (darkness).		Rickets.	Rickets.	Rickets.
247		30	30				"	"
248		20	24				"	"
436		40	50			Rickets.*		
437		44	50			" *		
438		50	60			"	Rickets.	Rickets.
249	No. 84	44	54			Negative.	Negative.	Negative.
250		36	40	15 min. (24 days).	6	"	"	"
251		30	32			"	"	"
439		42	52			"	"	"
440		40	52	15 " (14 ").		"	"	"
441		50	56		8	"	"	"
442		44	50	30 " (9 ").		"	"	"
262	No. 84 + 25 mg. of K_2HPO_4.	54	70	None (darkness).			Rickets.	Rickets.
263		52	72			Rickets.	"	"
264		44	64			Slight.	"	"
443		30	40			Rickets.*		
444		34	48			"	Slight.	Slight.
445		34	50			" *		

259	No. 84 + 25 mg. of K_2HPO_4.	40	60	15 min. (27 days).	8	Negative.	Negative.	Negative.
260		48	66			"	"	"
261		50	76			"	"	"
121	No. 84 + 75 mg. of K_2HPO_4.	40	45	None (darkness).			Negative.	Negative.
122		32	50			Negative.	"	"
123		26	44				"	"
449		30	40			Rickets.	Slight.	Very slight.
450		34	46			Slight (?).	Negative.	Negative.
451		32	40			"	"	"
124	No. 84 + 75 mg. of K_2HPO_4.	36	52	Indefinite.		Negative.	Negative.	Negative.
125		36	36			"	"	"

* Animals not killed; used for curative experiment.

were subjected to microscopic examination, and the final criterion as to the presence of rickets was the histological, rather than the radiographic picture.

Experiments with sunlight are difficult to carry out satisfactorily on account of the variability in the degree of sunshine, which makes exact quantitative work impossible. Nevertheless, as shown in Table I, daily exposures of 15 minutes sufficed to protect rats, fed a standard rickets-producing diet, which was adequate in its calcium but inadequate in its phosphorus content. This diet contained about 86 mg. of phosphorus per 100 gm. of diet; the addition of about 75 mg. of phosphorus to this diet is required to protect rats from rickets (Diet 85). The effect of sunlight may, therefore, be stated to have been equivalent to about doubling the quota of phosphorus. In considering the qualitative variability of the sun, it was noted in two series of experiments, not included in the tables, that the same degree of protection could not be obtained during November and December in rats on this diet. No doubt this is to be ascribed to the comparative lack of ultra-violet radiation furnished by the sun in the temperate zone at this season of the year, and is a factor to be considered in employing heliotherapy in infantile rickets.

As stated elsewhere, the potency of the sun is lost after its rays have traversed window glass (3). This observation is confirmed by experiments on rats. In the tests which are shown in Table II flint glass, 3.5 mm. in thickness, was employed. In another experiment window glass, 4.1 mm. in thickness, was employed with radiations from the mercury vapor lamp, as well as from the carbon arc lamp, for periods of 15 minutes. In both of these tests the animals developed marked rickets. A spectrogram of the second glass filter,[1] demonstrated that it obstructed rays shorter than 334$\mu\mu$ in length.

Another experiment was devised so that the sunlight was reflected from a smooth white surface and did not impinge directly on the rats. It will be noted (Table II) that this arrangement permitted access of a certain amount of effective radiation to the animals, an amount not adequate to protect them, but sufficient to prevent the development of the severe grade of rickets which came about either in darkness or when window glass was interposed.

[1] This was supplied by the Corning Glass Works, Corning, N. Y.

TABLE II.

Protective Experiments with Sunlight.
Direct, Transmitted, and Reflected Light.

Rat No.	Diet.	Weight.		Sunlight exposure.		Rickets.			Inorganic P per 100 cc. of blood.
		Initial.	Final.	Length of time daily.	Total.	Radiogram.	Pathological examination.		
							Gross.	Microscopic.	
		gm.	*gm.*		*hrs.*				*mg.*
528	No. 84	56	70	None (darkness).		Rickets.	Rickets.	Moderate.	5.2
530		48	60			"	"	"	4.9
535	No. 84	60	72	Direct.		Negative.	Negative.	Negative.	
536		60	68	30 min. (12 days).	20	"	"	"	
524		48	54	60 " (14 ").		"	"	"	
532	No. 84	60	70	Transmitted.		Rickets.	Rickets.	Moderate.	3.75
533		52	54	30 min. (12 days).	20	"	"	"	3.11
534		58	60	60 " (14 ").		"	"	"	
525	No. 84	40	60	Reflected.		Rickets.	Rickets.	Slight.	3.0
529		50	70	30 min. (12 days).	20	"	"	"	3.0
527		56	72	60 " (14 ").		"	"	"	2.5

Experiments with the Mercury Vapor Quartz Lamp.

The rays from the mercury vapor lamp have been used successfully in infantile rickets by Huldschinsky (4) and others. They have also been employed in experimental rickets by Powers, Park, and their associates (5), and by Hess, Unger, and Pappenheimer (3). The rays of this lamp are referred to sometimes as artificial sunlight, but differ markedly from those of the sun in that their spectrum is linear and not continuous, and they do not extend so far in the region of the infra-red but much further in the region of the ultra-violet. Table III demonstrates that they are capable of affording marked protection against rickets when given in small amount. It is not necessary to treat the animals with the rays for hours, as has been done in previous experiments. With an alternating current of 160 volts, exposures of 3 minutes or less, at a distance of 3 feet, were found quite sufficient to accomplish this result. It may be noted also that these animals failed to develop rickets in spite of the fact that the content of inorganic phosphate of their blood was far below the normal. In many instances, as reported by Gutman and Franz (6), only 4 mg. was obtained per 100 cc. of blood, whereas the normal content is frequently as high as 8 or 9 mg., when measured according to the method of Bell and Doisy. In rachitic rats which were kept in the dark and fed this diet, these investigators found the average inorganic phosphate to be 3.2 mg. per 100 cc. of blood. Kramer and Howland (7) described a greatly diminished concentration of inorganic phosphate in rats rendered rachitic by a diet deficient in phosphorus and in the organic factor contained in fats.

An attempt was made to protect rats from rickets by irradiation before they were placed on the experimental diet. To this end a series of animals was rayed for 6 minutes daily, at a distance of 3 feet, for a period of 5 days. It was found, however, that this preliminary irradiation did not delay the onset of the rachitic lesions or decrease their intensity, so that it may be inferred that this treatment did not enable the animals to store or mobilize any protective substance in their tissues.

There are at least three factors which determine the effect of light—the diet, the rate of growth, and the degree of pigmentation of the

skin. The question of diet and rate of growth will be referred to in the discussion of subsequent experiments. The importance of the relation of skin pigment can be demonstrated by a simple experiment (Table IV). If two groups of rats, one composed of white rats and the other of black rats (the melanotic form of the Norway rat), are given the minimal protective dose of light, it will be found that although diet and rate of growth have been the same, the black rats will develop rickets, whereas the white rats will show no rachitic lesions (Figs. 1 to 3). The table presents the results of radiographs and gross and microscopic examinations of two groups of rats subjected to a test of this kind. It is manifest that the protective rays were rendered comparatively inert by the integumentary pigment.[2] The applicability of this experiment to infantile rickets, especially to the well recognized susceptibility of the negro infant, is so evident as to require no further comment.

Experiments with the Carbon Arc Lamp.

A large number of experiments has been carried out with the carbon arc lamp. In view of the fact that its spectrum resembles sunlight more closely than that of the mercury vapor lamp, it seemed as if this source of light might be of value in rickets. This was found to be the case both in experimental and in infantile rickets. By means of this therapeutic agent rickets in infants can be readily cured, and the cure is accompanied by a surprisingly rapid augmentation of the inorganic phosphate of the blood (8). In a large series of young rats it was found that daily exposures of 3 minutes, at a distance of 3 feet, regularly prevented the occurrence of rickets, and that 2 minute exposures sufficed frequently under these conditions. When the animals were irradiated only every other day, slight rickets developed (Table V). Furthermore, treating with the rays at a distance of 6 feet for 1 hour afforded protection, although at a distance of 9 feet the same period of exposure proved inadequate.

[2] In one experiment (Table IV, Rats 589, 592, 593, 594, and 597) a somewhat larger amount of irradiation was given and protection followed. This shows that the pigment is not to be regarded as an absolute filter of ultra-violet rays.

TABLE III.

Protective Experiments with the Mercury Vapor Quartz Lamp. Variations in Duration of Exposures.

Rat No.	Diet.	Weight.		Irradiation.		Rickets.			Inorganic P per 100 cc. of blood.
		Initial.	Final.	Exposure.	Distance.	Radiogram.	Pathological examination.		
							Gross.	Microscopic.	
		gm.	*gm.*	*min.*	*ft.*				*mg.*
528	No. 84	56	70	None (darkness).		Rickets.	Rickets.	Moderate.	3.07
530		48	60			"	"	"	
598		88	90			"	Marked.	"	3.0
568		36	58			"	"	"	2.45
569		38	54			"	"	"	2.0
726	No. 84	42	50	½	3	Rickets (?).	Slight.	Slight.	727 2.47
727		44	50			Negative.	Very slight.	" (osteoporosis).	729 2.47
728		42	44			"	" "	Minimal.	3.0
729		40	44			Slight.	Slight.	Partial protection.	
722	No. 84	40	40	1	3	Negative.	Very slight.	Slight (healing).	4.56
723		50	50			Rickets.	Slight.		
724		52	64			"	"	" "	3.95
725		50	50			"	Very slight.	"	
872	No. 84	74	80	3	3	Negative.	Negative.	Negative.	4.5
873		50	50			"	"	"	
874		70	64			"	"		4.2
875		70	54			"			

730	No. 84	44	52	15	3	Negative.	Negative.	Negative.	
731		42	50			"	"	"	
732		42	50			"	"	"	
733		44	50			"	"	"	
570	No. 84	40	54	½, 1, 1½, 2	3	Negative.	Very slight.	Negative. }	3.75
571		40	56			"	" "	" }	
599		90	92			" (flattened out).	Slight.	Minimal.	3.6
600	No. 84	90	95	1, 2, 3, 6	3	Negative.	Negative.	Negative.	5.35
572		36	50			"	"	" }	
573		40	58			"	"	" }	5.42
574	No. 84	38	50	2, 4, 6, 12	3	Negative.	Negative.	Negative. }	3.8*
575		38	50			"	"	" }	
601		98	100			" (flattened out).	"	"	4.34

* Test questionable.

TABLE IV.

Protective Experiments with the Mercury Vapor Quartz Lamp. White and Black Rats.

Color of rat.	Rat No.	Diet.	Weight.		Irradiation.		Rickets.			Inorganic P per 100 cc. of blood.
			Initial.	Final.	Exposure.	Distance.	Radiogram.	Pathological examination.		
								Gross.	Microscopic.	
			gm.	*gm.*	*min.*	*ft.*				*mg.*
White.	860	No. 84	70	70	1	3	Negative.	Negative.	Negative.	
	861		58	60			"	"	"	
	862		60	70			"	"	"	
White.	857	No. 84	60	80	1½	3	Negative.	Negative.	Negative.	5.45
	858		64	70			"	"	"	4.44
	859		62	70			"	"	"	
Black.	854	No. 84	50	60	1	3	Rickets.	Marked.	Extreme.	
	855		50	60			Moderate.	"	Rickets.	
	856		60	58			"	"	"	
Black.	851	No. 84	50	50	1½	3	Moderate.	Marked.	Marked.	2.92
	852		48	54			Marked.	"	"	3.00
	853		60	60			" (fracture).	Very marked.	"	
Black.	589	No. 84	90	100	½, 1, 1½, 2	3	Negative.	Very slight.	Negative.	4.11
	592		48	70			"	" "	Very slight.	3.22
	593		50	56			"	" "	Rickets.	2.90*
Black.	594	No. 84	84	100	1, 2, 3, 6	3	Negative.	Negative.	Negative.	4.41
	597		36	48			"	"	"	

* Test questionable.

The protective effect of carbon arc light was tested also on rats fed more complex diets. Table VI shows that this source of light was effective when Diet 84 was amplified with serum albumin, egg albumin, or butter; in each instance a small amount of secondary potassium phosphate was added to compensate for the diminution of phosphorus incidental to replacing 5 or 10 per cent of the flour. Similar success was obtained with a diet amplified with dried milk. For some months experiments have been in progress with a diet containing dried milk, with the object of rendering Diet 84 more complete, and at the same time providing a food which more nearly resembles the dietary of the infant. It has been found that rickets will develop if, to a dietary composed of patent wheat flour and a simple salt mixture, about 10 per cent of dried milk (desiccated by the roller process) is added. It may be found that a diet containing 5 to 10 per cent of dried milk will be of value in investigations of experimental rickets in rats. The animals which received this more complete food were protected from rickets by irradiations of 4 minutes. Moreover, they grew exceptionally well. Whereas on Diet 84 rats increase about 10 gm. in weight in the course of the experimental period, some of the animals on this diet increased 30 gm. during the 26 days which comprised the experiment (Table VI). The factor of growth is of great importance in a consideration of measures which protect against rickets, as rapid growth tends markedly to the development of rickets. Protection afforded while the rate of growth is rapid indicates, therefore, increased potency of a therapeutic agent.

As demonstrated by McCollum, Simmonds, Shipley, and Park (9), rickets may be induced in young rats, on a diet low in phosphorus and high in calcium, or, on the contrary, on a diet low in calcium and high in phosphorus. Diet 84 is the prototype of the former diet and, as shown above, fails to induce rickets when the animals are exposed daily to a few minutes irradiation with the carbon arc lamp. Diet 85C is the prototype of the low calcium and high phosphorus diet, and regularly brings about rickets, although of somewhat different type from a histological point of view. Rats maintained on this diet were protected by light as readily as those on the low phosphate ration (Table VII), a result which suggests that light is able to compensate,

TABLE V.

Protective Experiments with the Carbon Arc Light.
Variation in Duration and Distance of Exposures.

Rat No.	Diet.	Weight.		Irradiation.		Rickets.			Inorganic P per 100 cc. of blood.
		Initial.	Final.	Exposure.	Distance.	Radiogram.	Pathological examination.		
							Gross.	Microscopic.	
		gm.	*gm.*	*min.*	*ft.*				*mg.*
698	No. 84	24	30	½, 1, 1½	3	Slight.	Rickets.	Slight.	
699		40	50			Moderate.	"	Marked.	
700		44	54			Slight.	"	"	
696	No. 84	44	58	1, 2, 3	3	Slight.	Slight.	Slight.	
697		34	50			"	"	"	
1015	No. 84	54	64	3	3	Negative.	Negative.	Negative.	
1016		30	30			"	"	"	
1017		60	70			Slight.	Very slight.	Minimal.	
980	No. 84	50	70	4	3	Negative.	Negative.	Negative.	
981		80	84			"	"	"	
982		60	62			"	"	"	
983		50	60			"	"	" (slight osteoporosis).	
900	No. 84	54	70	5	3	Negative.	Negative.	Negative.	
893		80	80			"	"	"	
906		40	44			"	"	"	
907		44	50			"	"	" (slight osteoporosis).	

892	No. 84	80	84	10	3	Negative.	Negative.	Negative.	3.2
908		50	50			"	"	"	
901		40	30			"			
909		50	44			"	Negative.	Negative (slight osteoporosis).	
803	No. 84	50	62	15	3	Negative.	Negative.	Negative (osteoporosis).	5.4
804		44	58			"	"	Negative.	4.76
805		42	60			"	"	"	
806		56	64			"	"	" (osteoporosis).	4.44
749	No. 84	30	40	60	3	Negative.	Negative.	Negative.	
750		34	42			"	"	"	
751		50	60			"	"	"	
752	No. 84	30	40	60	6	Negative.	Negative.	Negative.	
753		30	38			"	"	"	
754		54	60			" (?).	" (?).	Minimal.	
759	No. 84	22	24	60	9	Slight.	Slight.	Slight.	
760		28	38			Moderate.	"	Moderate.	
761		24	30			"	Moderate.	"	
762		20	30			Slight.	Slight.	Slight.	
1125	No. 84	30	40	5 (every other day).	3	Moderate.	Marked.	Marked.	
1126		50	56			"	Slight.	Slight.	
1127		50	54			Marked.	Marked.		
1128		50	60			"	Slight.	Slight.	

TABLE VI.

Protective Experiments with the Carbon Arc Light.
Effect of Diet.

Rat No.	Diet.	Weight.		Irradiation.		Rickets.			Inorganic P per 100 cc. of blood.
		Initial.	Final.	Exposure.	Distance.	Radiogram.	Pathological examination. Gross.	Pathological examination. Microscopic.	
		gm.	*gm.*	*min.*	*ft.*				*mg.*
1015	No. 84	54	64	3	3	Negative.	Negative.	Negative.	
1016		30	30			"	"	"	
1017		60	70			Slight.	Very slight.	Minimal.	
980	No. 84	50	70	4	3	Negative.	Negative.	Negative.	
981		80	84			"	"	"	
982		60	62			"	"	"	
983		50	60			"	"	" (slight osteoporosis).	
996	No. 84 + 10 per cent serum albumin + 50 mg. of K_2HPO_4.	60	60	4	3	Negative.	Negative	Negative (osteoporosis).	5.0
997		68	70			"	"		
998		60	68			"	"	" (moderate osteoporosis).	6.6
999		60	70			"	"	Negative (osteoporosis).	
992	No. 84 + 5 per cent butter + 25 mg. of K_2HPO_4.	54	60	4	3	Negative.	Negative.	Negative.	5.4
993		60	64			"	"	"	
994		60	54			"	"		5.0
995		70	80			"	"	Negative.	

984	No. 84 + 10 per cent egg albumin + 50 mg. of K_2HPO_4.	58	64	4	3	Negative.	Negative.	Negative (slight osteoporosis).	4.45
986		60	64			"	"	Negative.	
985		60	88			Slight.	"	"	4.8
987		40	60			"	Very slight.	Minimal (healing).	4.0
1018	7.2 per cent dry milk + 5 per cent No. 84 salt mixture* + 87.8 per cent patent wheat flour.	48	62	None.		Moderate.	Marked.	Moderate.	4.45
1019		54	74			"	Moderate.	Slight.	5.0
1020		50	70			Marked.	"	"	
1021		50	64			"	"	"	
1022	11 per cent dry milk + 5 per cent salt mixture + 84 per cent patent wheat flour.	50	70	None.		Moderate.	Moderate.	Slight.	7.15
1023		60	90			"	Marked.	"	6.66
1024		50	80			"	Moderate.	Moderate.	5.0
1025		50	70			"	"	Slight.	
1294	10 per cent dry milk + 5 per cent salt mixture + 85 per cent patent wheat flour.	64	100	4	3	Negative (?).	Very slight.	Negative.	
1295		30	60			" (?).	" "	"	
1296		38	64			" (?).	" "	"	

* Calcium lactate ..... 2.9 per cent.
Sodium chloride ..... 2.0 per cent.
Ferric citrate ..... 0.1 per cent.

TABLE VII.

Protective Experiments with the Carbon Arc Light.
High Phosphorus, Low Calcium Diet.

Rat No.	Diet.	Weight.		Irradiation.		Rickets.		
							Pathological examination.	
		Initial.	Final.	Exposure.	Distance.	Radiogram.	Gross.	Microscopic.
		gm.	*gm.*	*min.*	*ft.*			
975	No. 84	50	72	15	3	Negative.	Negative.	Negative.
976		62	67			"	"	"
977	No. 85C*	47	50	15	3		Negative.	Negative.
979		35	37				"	Almost negative.
419	No. 85C	40	36	None.		Negative (?).		Rickets (atypical).
420		46	42			" (?).		" "
421		52	50			" (?).		" "
422		54	53			" (?).		" "

* Patent flour..... 95.0 per cent.
Sodium chloride..... 2.0 per cent.
Potassium phosphate (secondary)..... 2.9 per cent.
Ferric citrate..... 0.1 per cent.

to an important degree, for a dietary deficiency of either calcium or phosphorus.

It seemed worth while to ascertain whether variations of temperature exert an effect on the protective action of light. For many years some have attributed the low incidence of infantile rickets in southern countries and in the tropics to the favorable influence of heat. Furthermore, ordinary chemical reactions are markedly accelerated by an increase of temperature. The test was planned so as to bring about a range of temperature of about 10°C. In order to accomplish this, some groups of rats were treated with the rays at room temperature, whereas others were placed in cages superimposed on ice. By this means temperatures of 29°, 23°, and 18°C. were established. The exposures were made for the standard period of 3 minutes at a distance of 3 feet. As shown in Table VIII fully as great protection was afforded at 18°C. as at 29°C., almost no rickets developing in groups of rats exposed at either temperature. The effect of lower or of higher temperatures was not tested.

CONCLUSION.

Young rats on a diet low in phosphorus can be protected from rickets by irradiations with sunlight for about 15 minutes daily. In the winter months, however, this degree of light was found insufficient. The effective rays of the sun, in the intensities studied, did not penetrate window glass. They manifested some protective value after reflection from a smooth white surface.

Irradiation of a few minutes with the rays of the mercury vapor lamp suffices to protect rats against rickets. This is true likewise of the rays from the carbon arc lamp. A standard protective dose of radiation can be formulated for rats on a standard diet.

Light is able to prevent the occurrence of rickets in rats fed a rickets-producing diet characterized either by a low phosphorus and high calcium content, or a high phosphorus and low calcium content.

Moderate variations in temperature do not alter the effective action of light rays. Pigmentation of the skin markedly lessens their effect, as demonstrated by the failure of a standard dose to protect black rats.

TABLE VIII.

Protective Experiments with the Carbon Arc Light.
Effect of Temperature.

Rat No.	Diet.	Weight.		Irradiation.		Temperature.	Rickets.			Inorganic P per 100 cc. of blood.
							Radiogram.	Pathological examination.		
		Initial.	Final.	Exposure.	Distance.			Gross.	Microscopic.	
		gm.	*gm.*	*min.*	*ft.*	°C.				*mg.*
1015	No. 84	54	64	3	3	29	Negative.	Negative.	Negative.	
1016		30	30				"	"	"	
1017		60	70				Slight.	Very slight.	Minimal.	
980	No. 84	50	70	4	3	29	Negative.	Negative.	Negative.	
981		80	84				"	"	"	
982		60	62				"	"	"	
983		50	60				"	"	" (slight osteoporosis).	
892	No. 84	80	84	10	3	29	Negative.	Negative.	Negative.	3.2
908		50	50				"	"	"	
901		40	30				"			
909		50	44				"	Negative.	" (slight osteoporosis).	
1075	No. 84	70	80	3	3	23	Negative.	Negative.	Negative.	
1076		60	64				"	"	"	
1077		50	68				"	"	"	
1078		30	38				" (?).	"	Almost negative.	
1071	No. 84	40	54	4	3	23	Negative.	Negative.	Negative.	
1072		40	50				"	"	" (slight osteoporosis).	
1073		42	50				"	"	"	
1074		36	48				"	"		

902	No. 84	50	50	10	3	23	Negative.	Negative.	Negative.	4.0
903		44	60				"	"	"	
904		50	50				"	"	"	3.65
905		44	50				"	"	" (osteoporosis).	
1083	No. 84	50	50	3	3	18	Negative.	Negative.	Almost negative.	
1084		50	50				"	"	Negative.	
1085		48	54				Very slight.	Very slight.	Minimal (healing).	
1086		50	54				Negative.	" "	Almost negative.	
1079	No. 84	50	54	4	3	18	Negative (?).	Negative.	Negative.	
1080		50	40				"	"	" (marked osteoporosis).	
1081		50	60				" (?).	"	Almost negative.	
1082		50	50				"	"		
933	No. 84	50	50	10	3	18	Negative.	Negative.	Negative.	
934		50	50				"	"	" (osteoporosis).	
935		48	50				"	"	"	
936		50	50				"	"	"	

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EXPLANATION OF PLATE 43.

FIG. 1. Rat 859 (white). 31 days on Diet 84. Daily exposure to the mercury vapor quartz lamp for 1½ minutes at a 3 foot distance. Rib: The zone of proliferating cartilage is normal. The zone of preparatory calcification (Pr_1) averages four cells in depth; matrix calcified. Complete calcification of spongiosa (*Sp*) and cortex (*Co*). No visible osteoid. No rickets. Decalcified in Müller's fluid for 5 days. Hematoxylin-eosin.

FIG. 2. Rat 853 (black). 31 days on Diet 84. Daily exposure to the mercury vapor quartz lamp for 1½ minutes at a 3 foot distance. Rib: The zone of preparatory calcification (Pr_1) is almost wholly free from calcium, and is greatly increased in depth and prolonged into the metaphysis. There is great excess of perichondral (*Pc*) and subchondral (*Sc*) osteoid. Marked rickets. Decalcified in Müller's fluid for 5 days. Hematoxylin-eosin.

FIG. 3, *a* and *b*. (*a*) Radiogram of the knee joint from a black rat (No. 853), showing marked rickets with fracture of the tibia. (*b*) Radiogram from a white rat (No. 859), showing a normal epiphyseal line.

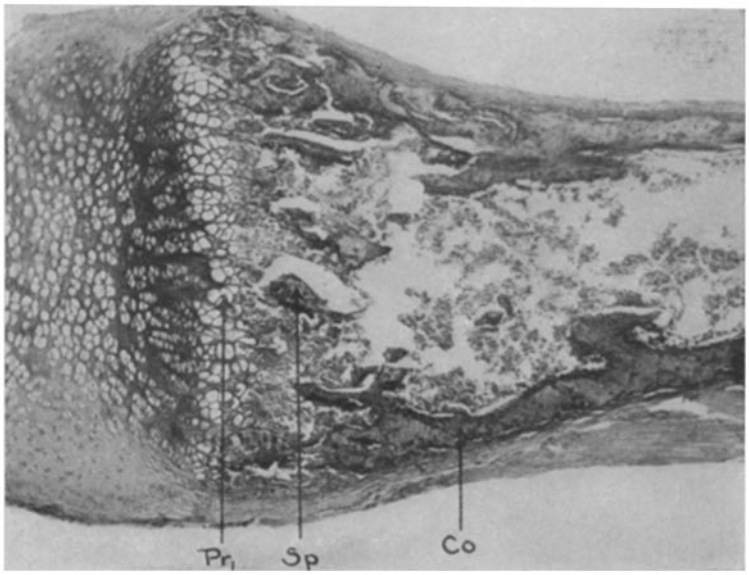

FIG. 1.

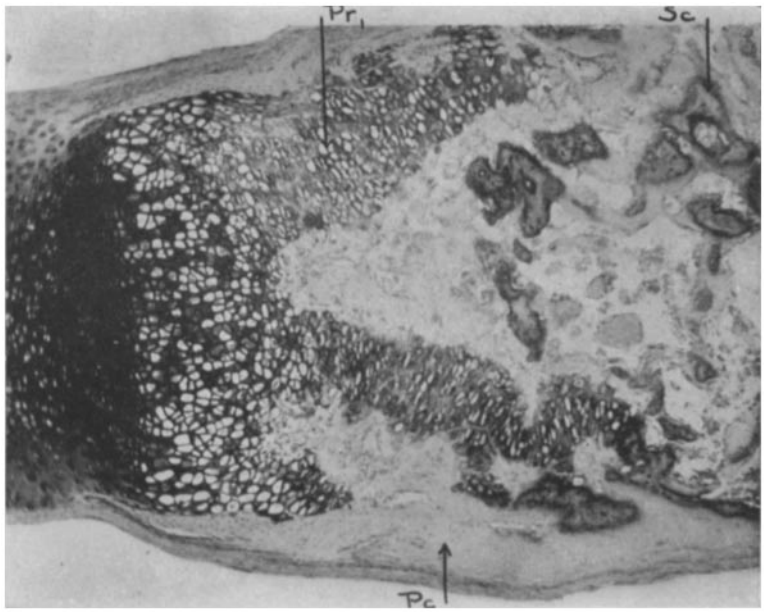

FIG. 2.

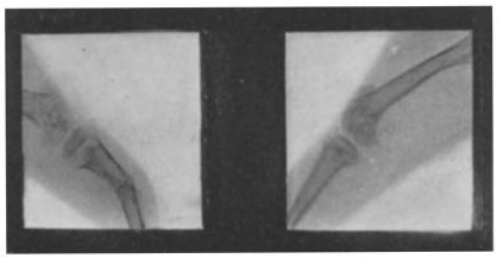

FIG. 3, *a*. FIG. 3, *b*.

(Hess, Unger, and Pappenheimer: Experimental rickets. VII.)