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Osteomalacia in China

By J. PRESTON MAXWELL, M.D. (Lond.), F.R.C.S. (Eng.),
Professor of Obstetrics and Gynæcology, Peking Union Medical College,
and
LEE M. MILES, M.D.,
Associate in Obstetrics and Gynæcology, Peking Union Medical College.

(Contribution from the Department of Obstetrics and Gynæcology, Peking Union Medical College).

HISTORY.

THERE is no evidence as to when osteomalacia first appeared in China. We have not so far come across any mention of it in the old obstetrical works, one of which dates back to at least 500 years before Christ. Even in the books belonging to the Kang Hsi and Chien Lung periods, there does not seem to be any recognition of the disease as an entity, and yet it is one which ought to have been recognized, as its consequences are so dramatic and the suffering it causes so great.

It must be remembered that the parts of China which are most cursed with the disease—namely, Shansi and Shensi—are provinces which, in the early days, were very sparsely populated. Northern Shensi is still in this condition, and as to Northern Shansi the disease was certainly there in quantity fifty years ago. Since even in the West it does not seem to have been recognized as an entity before the end of the sixteenth century, it is perhaps hardly surprising that there are no definite records of it in China. The first record in Europe appears to have been one by Lambert in 1700 A.D. (Ribemont-Dessaignes). Subsequently Mme. Supiot, in 1747, and Morand fils, in 1752, wrote on this subject, and in 1768 Cooper performed Cæsarean section for pelvic deformity and obstruction caused by the disease. In the New World the first

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case reported is one occurring in Pennsylvania in 1742, a record of which is found in the Royal Society's Transactions for that year.

Distribution.

As far as China is concerned, the distribution is as follows: The heaviest incidence is found in the northern three-fourths of the province of Shansi, the southern limits being Luanfu on the east and Pingyangfu on the west. It is not evenly spread over the province, the incidence being especially heavy about the centre of this region; at Pingtingchow, Shouyang, and Yütze. In these places the incidence is surprisingly marked.

We selected Pingtingchow as the special place for our study of the disease partly because of the high incidence there, and partly because in that city there is a well-equipped Medical Mission Hospital whose head, Dr. F. J. Wampler, has been much interested in the disease and has given us the heartiest help and co-operation, working with us on this question, and its severity there will be readily realized when we tell you that in one week one of us saw twenty-two well-marked cases in part of the city and one of the suburbs. The whole city and suburbs contain about 15,000 inhabitants, and it is probable that at least one in fifty of the women of child-bearing age have, or have had, the disease. We know of one family at Pingtingchow in which three daughters-in-law died one after the other from obstructed labour due to osteomalacia. The Chinese themselves claim that the incidence may rise as high as 10 per cent. of the child-bearing women of adult age. When one takes the hospital records of the capital of the province, Taiyuenfu, which is close to the Yütze region, we find that during the last twelve years there have been close on one hundred Cæsarean sections performed in the Mission Hospital on patients suffering from this disease. A large number of Cæsarean sections have also been done at Taiku, Fenchow, Pingtingchow, and Liaochow. The whole affected area is on a high plateau, 2,000 to 3,000 feet above the sea.

In Shensi it is the northern half of the province which is affected. This is very mountainous. There are few cities and the population is a scattered one. The incidence in this region is probably about 1 per cent. or 2 per cent. of the women of child-bearing age, and there are probably 2 per cent. to 3 per cent. of pregnant women who die in labour from this disease. The lack of a series of vital statistics makes the estimation of these figures a matter of some doubt, but the incidence is undoubtedly very heavy.

The area in Shensi does not extend south as far as the Sianfu line, and speaking generally, is much above sea level.

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In the province of Kansu, the middle belt, which is a high tableland, is affected. There have been cases both at Lanchow and Pingliang, but there are very few medical men with Western training in the province, and it is not known whether the incidence is really heavy. From enquiry I doubt whether it occurs in anything like the proportion in Shansi and Shensi. It is also a question whether it occurs to any extent among the Mohammedans.

A letter from Dr. George E. King, of Lanchow, dated June 23rd, 1924, tells one of us that there have been six Cæsarean sections there for osteomalacia during the first half of the year. Another case was waiting for operation as he wrote. One of these cases was in a Mohammedan, so it undoubtedly occurs among them.

The whole of Manchuria is affected with the disease, cases having occurred as far south as Newchwang, as far north as Ashiho, and in the centre as at Mukden and Liaoyang. But it is of a distinctly milder type than the Shansi type, and Cæsarean sections for deformity of the pelvis are much rarer occurrences.

There are also several small areas where the disease is present scattered about the Republic.

There is a tiny area near Changsha, Hunan, where the major trouble for which the patients came to the Hunan-Yale Hospital was deformity of the chest. At the same time one of us investigating on the spot obtained information of one case in this region which had died in labour from pelvic obstruction due to osteomalacia. There have been no Cæsarean sections at the Hunan-Yale Hospital due to this disease.

There is another small area around Kongmoon, in the Canton province, and not only has osteomalacia been seen at that place in Chinese, but an Australian woman developed the disease there. She was married to a Chinese, and had been living with and as the Chinese, so that she was subject to the same causes which act in their case. With the exception of this one, we have heard of no other foreign case developing in China.

Another small area is around Suifu, in the province of Szechwan, and there is another small patch around Kweiteh, in north Honan. Occasional cases occur in Peking and the province of Chihli, and at one time there were a number of cases in an area on the outskirts of Tientsin, but the disease does not seem to be prevalent there at the present time.

Osteomalacia used to be fairly common in Europe, especially in the Rhine Valley, the Danube Valley, and parts of Italy and Flanders, but it is now almost a negligible item in these regions.

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Hunger malacia was frequently seen in Austria and part of Germany during 1918, but has now disappeared.

In the East it is found in India, widely scattered. Scott reports its incidence to be heavy in Kashmir and the Punjaub. In Japan it is also present, especially in the province of Toyama, where Ogata met with many cases.

Section II.

General Picture of the Disease.

What is the general picture of osteomalacia as seen in China? One meets with mild cases as well as severe ones. As known by the patient it goes under the name of "Yao T'ui T'eng," or "back and thigh pain." In some cases pain in the lumbar region precedes that in the thighs. It is of an aching character, coming and going, better some days than others, and worse during the winter months than in the summer. There may be pain alone and apparently no bone change, although even in these cases, on X-ray examination, there is evidence of the disease in transparency and mottling of the bone-shadows.

As a rule, however, the trouble progresses and the bones become distinctly tender, especially over the lower ribs and the pelvic girdle. The bones become soft in spots and the incidence of the disease on various areas of the bony system is erratic, and we cannot as yet explain the reason for the differences. One woman may suffer in the pelvis alone, another in the chest, and a third in both. There are also alterations in the long bones, so that a marked coxa vara may be produced, quite apart from the bendings which may appear in humerus or femur or elsewhere.

The affection of the pelvis takes a characteristic form. The sacrum becomes shortened by the development of a marked convexity backwards, so that the lower part tends, with the coccyx, to come forward and narrow the outlet; the acetabula are carried inward; the symphysis pubis splayed outward; and the descending rami of the pubes and the ascending rami of the ischia tend to approximate so that the vaginal outlet is almost blocked. The tuberosities may actually touch, and tend to be carried a little backward, so that the outlet of the pelvis may be reduced almost to the vanishing point. The upper strait of the pelvis becomes triradiate, and the last lumbar vertebra may slide a little forward, possibly aided by the alteration in the shape of the sacrum.

In the chest a lateral curvature with some rotation of the upper dorsal spine takes place, and the neck seems to sink into the upper portion of the chest, thus reducing the height by several

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inches. The chest itself tends to become barrel-shaped, the sternum crumples up, curves forward, and forms a marked prominence on the front of the chest wall, the distance from the suprasternal notch to the ensiform cartilage being reduced, in a bad case, to two inches or under.

The result of this deformity of the spine, combined with a developed weakness in the muscles, is that the patient tends to walk less and less, and sits on the "kang"* in a characteristic attitude, bending slightly forward and resting the weight of the head on a pillow. In some cases we have known, this attitude had been maintained for the best part of the year. The patient may come to the hospital complaining of inability to walk and thinks that she is suffering from paralysis.

In the long bones irregular curves take place, but as a rule these are distinctly rarer than the changes in the chest and pelvis. Fractures are not a marked feature of the disease in China. There is generally a little inflammation about the alveolar edge of the gums, not due to pyorrhœa, and in one case we specially studied this made eating difficult. Apparently the teeth are not directly affected, but the jaw is affected, so that the teeth, although perfectly healthy, tend to become loose and some of them may drop out. If they do not drop out, as the patient recovers they again become firm. Tetany is very common. Probably the majority of patients suffer from it at one time or another. Of the last four cases which were specially studied, three of them confessed to have had tetany. The fourth one declared that she had never had it, but she had a typical attack while under study in the hospital. The spasms may last for hours and then leave a numbness in the legs and arms. Or there may be the development of a numbness called by the people "ma mu," which is closely allied to tetany and often precedes it.

What is the ordinary history of one of these cases? A typical history would be as follows: First pregnancy, normal. Second pregnancy, pain during last few months, normal labour. Third pregnancy, pain beginning early in pregnancy, say about the third month, craniotomy or the forceps needed at time of labour. Fourth pregnancy, pain as already described but more severe, a difficult craniotomy or a Cæsarean section needed, birth of a living child in the ordinary way impossible.

This is the usually accepted text-book picture, and one meets many cases that correspond to it.

* The "kang" is a heated platform on which the ordinary person in North China sleeps. It is built of brick or dried earth-brick, and is heated by flues running in both a longitudinal and a transverse direction. It may be stoked from outside the house or from inside, and the fuel used is coal or sorghum stalks.

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But is this the normal course of events? Can one not go further back and find an earlier history? We believe that we can, and in this our opinion is borne out by King of Kansu, who speaks of the disease there as being one of girls before marriage, becoming worse or *recurring* in the pregnancy period. Wampler, of Pingtingchow, has also remarked to us on the number of cases in which there seem to be symptoms of osteomalacia during the puberty period. Further, and we throw this out more as a suggestion which we will again mention further on, it is possible that some at least of the funnel pelves are really the result of a mild puberty osteomalacia.

One of our most marked cases is that of a male in whom the symptoms began just before puberty, anl we know of one very well marked case in a woman in Pingtingchow in whom symptoms began at the age of 12—13.

But we are fortunately able to go further in this direction. Just before leaving Peking there came into our hands a paper by Mr. Liu Shih Hao, a student in the Peking Union Medical College, on two cases of tetany occurring in girls from an orphanage near Peking. Nothing had been noticed about the bones save that the X-ray evidence of rickets was absent. Considering, however, the history of tetany, the low blood calcium and the age of the girls, it was arguable that here were two cases in which there might very possibly be evidence of commencing osteomalacia. We sent for them back, had X-ray pictures taken of the pelvis and the latter measured. The measurements were as follows:—

Case 1.—Pai Jui Feng, æt. 15. Interspinous, 21; intercristal, 22; external conjugate, 14; interischial, 6.

Case 2.—Li Fu Chen, æt. 16. Interspinous, 22; intercristal, 24; external conjugate, 16.5; interischial, 6.5.

The bones were markedly calcium short, and gave weak pictures, and in the case that is most serious, a distinct deformity of the pelvis is already present. These cases will be further discussed when we come to the question of ætiology.

These cases show that it is probable that quite a number of young girls may have mild attacks of osteomalacia without their being suspected.

The disease may appear in the first pregnancy, and may progress so fast that a Cæsarean section may be necessary at the time of the first labour. Or the disease may appear in several successive pregnancies without causing much difficulty at labour, and then suddenly take on malignant characters, so that it is impossible for the next labour to take place naturally, and the

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only hope of the woman and child is a Cæsarean section. As a rule the disease clears up after lactation is complete, and may recur again and again; but some of the victims seem to have symptoms over many years, and in a minority the disease begins and steadily progresses, making the patients bed-ridden invalids, till they die of asthenia, or some intercurrent affection. Some of them die of pneumonia, but the affection follows no fixed course.

In a certain number the main symptoms of the disease appear immediately after the stopping of the calcium drainage or after the strain of labour, and may progressively increase for a time in spite of treatment. This is what McCrudden calls "over-production." As a rule, when the cause of the calcium drain ceases to become effective, there is a fairly rapid recovery from the condition with the disappearance of symptoms, even though the calcium loss in the bones may be gradually replaced. But in some cases the original cause seems to go on acting for a time in spite of the withdrawal of the stimulus, and this may explain the uncertain result of efforts in the direction of treatment.

Take for instance the following case, which also illustrates the rarer manifestations of osteomalacia in which the main symptoms seem to be referable to the soft parts. Here is a woman who in each succeeding pregnancy has suffered in increasing severity from the pains which are such a marked symptom of the disease, without the bones being markedly affected. There seems to be little doubt that one is dealing with a manifestation of this disease, the only tangible symptoms being the pain, increased reflexes and a diminution in the blood calcium.

Case No. 3928.—Li Hau Shih: Age 31, native of Chihli (Lanchow region). Family and past history good. Married when she was 25 years old. No dysmenorrhœa or leucorrhœa. A child was born in her 25th year, a second in her 27th year, a third in her 29th year, and a fourth in her 31st year. All four children were born at full time and are still alive and well.

The first three children were breast fed, at least for a number of months; the last one was only fed for a day or two at the breast.

In the first pregnancy the pain of osteomalacia began about two weeks after childbirth, and consisted of aching in the lumbar regions. It gradually disappeared and was gone after a year.

In the second pregnancy the pain came on at about the same time and lasted three months. It was more severe than in the first pregnancy.

In the third pregnancy the pain came on about the same time,

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but its distribution was wider in area, spreading into the thighs. It lasted five months, and was worse than in the second pregnancy. In spite of the pain she was able to get up and about during these three lactation periods.

In the fourth pregnancy the pain came on three days after childbirth and gradually spread, till after twenty days she had pain in her back, arms and legs. The pain was intermittent and aching, varying in duration from a few minutes to several hours. She was able to walk about with difficulty for about three weeks, and since then has been lying down owing to pain and weakness.

The muscles seem to be tender; the reflexes are a little increased; the electrical reaction of the muscles is normal. The grasp of the hand is weak and the patient does not move very readily. By the X-ray the bones are normal, save that they are a little more transparent than is usual. The blood is normal save for the blood calcium which, on admission, was only 6.8 milligrams per 100 cc. serum. The urine is normal. The joints appear to be perfectly normal and there is no œdema. The gums are a little inflamed, but the teeth are in good condition and there is no pyorrhœa. After three weeks in the hospital under treatment the blood calcium was 11.3 mg. per 100 cc. serum, that is, the normal figure. The pains were gradually diminishing and the patient was sleeping and eating well.

There are cases in which the weakness of the muscles seems to be the symptom of which most complaint is made, and patients may seek advice complaining that they are paralyzed and cannot walk. Two such cases have come under our notice lately. Whilst away from Peking one of us was appealed to on behalf of a patient who was said to have gradually become paralyzed three months after labour. One of our assistants was sent to investigate the case, and we speculated on its being an early one of osteomalacia. The report was not full enough to be certain of the diagnosis, but our assistant had put her on large doses of cod liver oil and calcium lactate, and she walked into our consulting room a fortnight to three weeks after this date.

In June, 1924, we had in the wards a woman who presented a typical picture of osteomalacia and had come down from Northern Shansi, a day and a half's journey to the hospital, as a case of paralysis.

To sum up this section: Osteomalacia is due to more symptoms than its name would imply. Contrary to the usual belief, it often begins about the age of puberty, and besides bone deformity within the pelvis and the chest, there are marked symptoms referable to the nervous system, the muscles and the teeth.

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Section III.

The Fœtus in Cases of Maternal Osteomalacia.

Some of the questions which arise in connexion with this disease are the following: What is the condition of the fœtus when the mother has osteomalacia? Does it suffer with the mother or is the entire brunt of the disease borne by her? If it suffers, considering the close relationship between osteomalacia and rickets, is there any evidence of prenatal rickets?

Having been unable to find any papers dealing with this subject we first of all took up this question under the impression that the entire brunt of the disease was borne by the mother. Apparently this is by no means the case. Seven fœtuses, delivered by Cæsarean section from mothers with obstructed labour due to osteomalacia, have been carefully examined. Five of these were at full time, the sixth at about seven and one-half months, and the seventh at eight months. All these fœtuses came from pure Chinese mothers; and for purposes of comparison bones from eight fœtuses, which were born of normal Chinese mothers and died from accidents of childbirth, seven being full time fœtuses and the eighth an eight months' fœtus, were also examined.

Roentgenograms show that the proper centres of ossification are present. Two out of three of the fœtuses, however, from mothers with active osteomalacia, showed curious changes about the ends of some of the bones, especially the ulna, the main change being an apparent cupping of the end of the bone, which at once suggested the possibility of this cupping being rickety in nature. There is not, however, in the Roentgenogram the irregular outline characteristic of a rickety cupping. The mothers of the other four were apparently suffering less from the disease than from the deformity.

The next step in the investigation was to remove specimens of these affected bones, the radius and ulna being selected. It was noted that the bones appeared to be a little smaller and possibly lighter than the normal, and that they could be split with a knife with greater ease than is usual in those coming from a normal fœtus. For comparison the same bones were also removed from a normal fœtus, which had died at full time from an accident of labour. The bones in this case were larger and harder. Even if some of these have certain differences, due to the size of the woman and the tendency of some women to have larger children than others, there is no doubt that the balance is heavily against the bone from the fœtus conceived by the mother with osteomalacia both as regards size and hardness; and to a less degree as to weight.

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Sections of these bones were now prepared and stained in various ways, and the following facts became at once evident:—

1. The amount of osseous tissue in the bone coming from the normal control was much greater than that in the osteomalacic fœtus. In other words, the bone from the fœtus in osteomalacia was ostein short.
2. In the specimen from the fœtus in osteomalacia the chondrin stained faintly, almost certainly due to a shortage of chondrin and a poor quality of chondrin.
3. In the normal control the zone of calcification was present, whereas in the bone of the fœtus in osteomalacia this zone was hardly, if at all, visible. There was no irregularity of the zone of calcification, nor a linking of the cell columns, such as one finds in rickets; and the appearance of the specimen rather bore out the *dictum*, that even if the diet is deficient in the proper proportion of its elements, the child will not develop rickets if the supply is at a starvation level. The appearance is more that of osteoporosis.
4. The apparent cupping of the ulna was due to a little advanced calcification on the two sides of the section below the periosteum.

TABLE I.

ANALYSIS OF FOETAL BONES - 1ST SERIES

Normal	Fresh Weight	Dry Weight	Ash Weight	Moisture per thousand	Organic Matter per thousand	Ash per thousand
1	15.885	5.0184	2.2176	690.375	170.022	139.603
2	15.180	4.678	2.0678	691.832	171.890	136.278
3	13.179	4.311	1.920	671.889	181.431	145.680
4	16.830	4.3237	1.7972	742.918	150.291	106.791
Osteo-malacia						
1	15.192	3.9022	1.3352	749.724	162.388	87.886
2	16.052	4.103	1.3861	744.394	169.256	86.350
3	7.895	1.708	.5925	783.382	141.571	75.047

ANALYSIS OF ASH

Normal	Calcium per 1000	Phosphorus per thousand	Magnesium per thousand	Osteo-malacia	Calcium per thousand	Phosphorus thousand	Mg. per thousand
A[x]	382.5	178.66	4.35				
1	388.66	184.76	13.22	1	380.65	188.04	4.60
2	383.2	189.05	11.38	2	373.88	186.88	2.16
3	277.22	187.79	8.61	3	364.20	186.47	8.10
4	379.64	187.12	2.48				

x Analysis of normal adult bone ash (femur) calculated from table on page 436, Hammarsten Physiological Chemistry Ad. Carnot.

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TABLE II.

ANALYSIS OF FOETAL BONES - 2ND SERIES

Normal	Sex	Weight	Duration of Pregnancy	Fresh Weight Femur	Dry Weight Femur	Ash Weight	Moisture per Thousand	Organic Matter per Thousand	Ash per Thousand
1	Male	2675	Term	16.175	4.9926	2.0908	691.34	179.40	129.26
2	Male	2315	Term	10.5540	3.1305	1.9818	703.38	187.78	108.84
3	Male	1730	8 Months	9.544	2.7676	1.1306	710.01	171.53	118.46
4	Female	2730	Term	15.053	4.3800	1.5635	708.68	187.33	103.99
			Foetuses from Mothers suffering with Osteomalacia						
1	Male	2350	Term	13.115	4.3977	1.7190	664.68	204.24	131.08
2	Female	2678	Term	16.085	5.0390	1.7898	686.73	202.00	111.27
3	Male	1695	8 Months	8.585	2.6552	1.0246	690.71	189.94	119.35
4	Male	2296	Term	16.570	4.9505	1.6053	701.23	201.89	96.88

Calcium and Phosphorus in the Ash - 2nd Series

Normal	Calcium per Thousand of Ash	Phosphorus per Thousand of Ash	Calcium per Thousand Bone	Phosphorus per Thousand Bone.
1	368.67	184.64	47.78	23.87
2	400.65	197.15	43.61	21.46
3	382.69	193.66	46.52	22.94
4	393.78	191.56	40.95	19.92
		Osteomalacia		
1	367.49	190.35	48.17	24.95
2	375.14	195.21	41.74	21.72
3	387.54	188.80	46.24	22.53
4	370.37	187.26	35.88	18.14

Turning from these appearances to the analysis of fœtal bones carried out by one of us (Miles), ample confirmation of the facts which have already been stated is found. The femur was taken as the test for this purpose, was carefully cleansed from all extraneous material and then analyzed, the result being given below.

The first table shows the results of one set of analyses, the second the result of a second set carried out a year later with an entirely new set of fœtuses.

When one looks at the first set of figures, it will be noticed at once that the proportions of the salts to one another as regards calcium and phosphorus are unaffected, but the difference in the ash per thousand is very marked, and one may safely say that there is a definite calcium and phosphorus deficiency as compared with normal bones. It is also clear that although there may be a retention of sulphur and magnesium during the active state of the disease the bones of the fœtus do not show it, as the magnesium count in the osteomalacia cases is distinctly low.

In the second set of figures this does not show up so clearly

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except in the case of the last fœtus from cases of osteomalacia, but it will be noted that the femora of the babies from osteomalacia mothers are relatively heavier in this series than those of the normal controls, the principal difference in weight being in the increased amount of organic matter in the bones.

It would seem from the two sets of analyses that the fœtus fails to get enough calcium when the mother's blood is deficient in this mineral. In considering the apparent variations in the figures it must be borne in mind, as we have already remarked, that it is difficult to be sure of the exact condition of the mother in these cases. Some of them at least were suffering more from the effects of old osteomalacia than from the disease itself, which has a considerable bearing on the figures obtained.

We know that as regards the first set of analyses the mothers all presented signs of active osteomalacia, but as to the second set of figures we are only sure of fœtuses 1 and 4. Fœtuses 2 and 3 certainly came from mothers in whom the disease was arrested.

As to the living, a fœtus delivered by Cæsarean section from a marked active case of osteomalacia, showed at the age of one and a half months certain changes in the ends of the femora.

The note concerning this child is as follows : Baby Chi (Mother's No. 2089), No. 2123. Peking Union Medical College Hospital. Cæsarean baby (for osteomalacia); carried very high owing to shape of pelvis. The child was very fond of lying almost prone with its knees drawn up. When one and a half months' old an X-ray was taken. There were slight changes in distal ends of femora. Dr. Hodges suggested that the child had rickets or lues. TheWassermann reaction was negative and the history of mother clean. Dr. Brackett examined specially for rickets, and confirmed our opinion that there were no clinical signs of this disease; he doubted whether X-ray findings were those of rickets, though he was not prepared to diagnose the cause of the slight changes in the femora. The baby went home fat and well, and was in good health two and a half years later, with no signs of rickets.

Dr. Hodges' report was as follows : " Stereoscopic films show more clearly the change in the distal ends of the femora suggested by flat films made on June 2nd. The changes consist in a flattening of the diaphyseal ends of the bones, but without any cupping. Probably rickets, possibly lues."

It is a question whether some of these children if placed under favourable conditions may not develop some of the Roentgenographic appearance of rickets as they recover from the osteomalacic influence. Dunham has published the account of such a case in which there is no doubt that the condition of the mother had a definite influence in the early appearance of rickets in the infant.

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If there is a definite calcium surplus in the full time fœtus in normal circumstances and a deficiency of this surplus in premature fœtuses (Hamilton), then one might expect that these fœtuses from mothers with osteomalacia would behave like premature fœtuses in exhibiting in a greater proportion than normal full time fœtuses symptoms of rickets early in life.

Dr. Alfred Hess kindly allows me to mention that in a series of Roentgenograms of neo-natal children he has found a certain amount of cupping of the ulna in about one in twenty of the cases. Exactly what interpretation is to be placed on this cupping is at present uncertain.

One notices when these children are born that the subcutaneous fat is deficient and the skin tends to be wrinkled, but this condition rapidly improves and otherwise the children appear to be perfectly normal. Another interesting point is that at the operation of Cæsarean section in mothers with osteomalacia, the omentum will be found to be shrunk and practically devoid of fat.

One may ask what is the condition of the blood of these fœtuses as regards the proportion of calcium. Here again one has carefully to distinguish between fœtuses born from mothers who have active osteomalacia and those born from mothers who have fully recovered from the disease. Apparently there is little divergence from the normal in these latter cases, and our figures for the calcium in the cord-blood average about 10.3 milligrams of calcium per 100 cc. of serum.

We have not enough data to be able yet to speak about the proportion of calcium in the cord-blood of fœtuses from cases of active osteomalacia.

Hess and Matzner give us a normal figure for the cord-blood 10.75 mgm. per 100 cc., and Bogert and Plass give 10.9 mgm. per 100 cc.

Conclusions.

(1) There are definite changes in the skeletal system of the fœtus born from mothers who are the subjects of osteomalacia.

(2) These changes are especially marked about the growing ends of the long bones and consist in a shortage of ostein, a poor quality of chondrin and an absence of a proper zone of calcifcation.

(3) When the bones are analyzed, although the elements are contained in their proper proportion, there is a general deficiency of the salts which should be present in a normal bone.

(4) There is no evidence of pre-natal rickets.

(5) The centres of ossification are apparently normal in position and time of appearance.

(6) The cord-blood calcium in fœtuses from cases of healed osteomalacia show little divergence from the normal though the divergence is in the direction of shortage.

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Section IV.

Ætiology.

Let us first try and clear the ground a little. Has the geological formation anything to do with the distribution of osteomalacia?

By the kindness of Dr. Ting, late of the Geological Department of China, we were able to secure a map of the Shansi formation. It has already been stated that the whole region is about 2,000—3,000 feet above the sea. Looking at the map one sees that a large number of the cases occur on loess formation, and on limestone, a further number on the sandstone, and in the north of the province over the archæan. There does not seem to be any selection of the areas covered by these formations in the incidence of the disease.

The water mostly falls away to the East and to the West, entering the Yellow River on the one side, and the rivers running into the Gulf of Pechihli on the other. The drinking water is mostly obtained from shallow surface wells, and the people as a rule drink little unboiled water. So that we think we may rule out the actual geological formation as having but little to do with the disease. The altitude, of course, causes the winters to be longer and more severe, and increases, especially in the case of bound-footed women, the confinement to the house.

Next let us consider the state of the ovaries. Although not generally put in this bold way, the ovaries have been considered as the cause of the disease, and their removal advocated on this ground. There is no evidence worth the name which proves the disease to be connected with pathological changes in the ovaries. One of us has carefully examined ovaries taken from active osteomalacia cases at the time of a Cæsarean section, and compared them with the ovary removed from a Cæsarean section case for another cause, and failed to find any histological difference. This entirely confirms the observations of previous observers as to the absence of histological changes. The mere fact that castration is followed by the clearing up of the main symptoms of the disease proves nothing. In some cases the immediate calcium loss has, after castration, been greater than before; and it is probable that castration, acts merely by preventing another pregnancy (which can be as easily done by tying the Fallopian tubes), and by arresting menstruation, which, of course, is a theoretical gain, as it stops the monthly drain of calcium. Against this theoretical gain has to be placed the premature menopause with its mental influence on bodily health. We do not remove the ovaries if sterilization is

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needed. We tie the Fallopian tubes if the patient does not wish for any more children, but if she did, we would have no hesitation in allowing a further pregnancy, even in cases of severe deformity, and delivery by Cæsarean section, assuring the woman that the disease would not again arise under proper treatment. And we have put this advice into practice without any recurrence of the disease following.

One of the latest theories as to ætiology is that of McCrudden. "Just as the subcutaneous fatty tissue acts as a store of fat and the liver glycogen as a store of carbohydrate, so the skeleton acts as a store of calcium salts, to be called on in time of need. During the later months of pregnancy and during lactation, the need for calcium salts is great, greater than the intake in the food, and it becomes necessary to draw upon the calcium supply in the bones. The result is that the new bony tissues laid down to replace old bone as it disappears, is poorer in lime salts than the normal. Ordinarily the quantitative change in the composition of the bones is not enough to produce symptoms. At the end of gestation and lactation when the extra need for calcium has ceased, normal bone is again laid down."

Hanau has brought forward some proof of this being the case and of there being a true physiological osteomalacia. But this theory only covers part of the truth. If the disability was as simple as this, one would only have to supply the calcium deficiency and all would be well.

There are two points which may be brought forward as controverting this simple view of the disease. *The first* is that in clinical practice it is not sufficient to supply only a sufficiency of calcium. For example, in one of our cases studied, although it was possible by the administration of calcium with vegetable oil to increase the blood calcium, yet this did not suffice to turn the negative calcium balance into a positive one, and the drain went on as before.

The second is that the theory fails to take into account the fact that a great many cases begin about puberty, when, although there is a calcium demand, this is not sufficient by itself to start the disease. And there are a few cases which appear to start after the menopause.

It will be recalled that three factors are believed to act in the case of rickets, a disease closely allied to osteomalacia; in fact, Von Recklinghausen states that they cannot be morphologically distinguished, when the histological appearances of the affected bones are alone considered. This, however, must be accepted with reserve, as it certainly does not apply to the areas of growth at the ends of the long bones.

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These three factors are:—

(1) A deficiency of diet,
(2) Lack of sunshine,
(3) Lack of movement.

To these three may possibly be added—(4) A toxic influence due to some change connected with the ingestion of certain forms of protein, as has been noted in experimental work by Mellanby. Reduced to another form, this implies that one must have for health:—

(*a*) A sufficient supply of salts, and suitable protein and carbohydrate;
(*b*) A sufficiency of the necessary vitamins;
(*c*) An activator for calcium metabolism, and this is bound up with the question of sunlight and movement.

Let us consider first the question of food:—

What is the ordinary food of these people? In their homes they live on a very meagre diet of cereals with a limited quantity of vegetables, and, as a rule, no meat, milk, or eggs; and but little animal fat, the oil used for cooking being mainly vegetable. The principal article of diet is millet, which is eaten at least once a day in the form of a thin gruel made of the whole seeds which have been partially hulled and boiled in water; and to this water is sometimes added a few small pieces of onion or garlic. A small quantity of salted vegetable, such as a variety of turnip or radish or bean leaves which have been preserved in brine, will be eaten with this gruel as a relish. About 15 to 20 grammes of this salted vegetable will be consumed at a meal.

Millet may also be prepared by dry steaming and produces a dish somewhat like steamed rice. But in the majority of instances it is consumed as gruel, and during the first month after labour this millet gruel in small quantities (not over four ounces of millet a day) may be the sole food.

Wheat flour products are eaten once a day by those who can afford the luxury. Steamed bread is made of wheat flour, or the dough is rolled out thin and is baked in large, flat, unleavened cakes. A third favourite way of eating wheat flour is in the form of noodles and usually in the noodles a proportion (usually about 25 per cent.) of flour made from green soy beans is added. This wheat flour varies from a white modern milled flour to a whole milled flour.

Occasionally oatmeal flour is used, in the form of ground oat-

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meal which has been partially roasted, but it does not form a main element in the food.

There are but few vegetables. A form of cabbage, marketed in the West as Chinese celery-cabbage, is eaten in large quantities throughout North China, but in the region affected by osteomalacia, which is mostly, as one has said already, on a high plateau, the season is short and the cultivation far from extensive. Thus the supply is limited and the price high, and as a consequence poor people and women get little of it. It is eaten boiled or fried, and the valuable green outer leaves are stripped off and little eaten, the bleached inner leaves being the most esteemed. Onions and garlic, salt vegetable prepared from the leaves of the soy bean, the leaves and stalks of the mustard plant, and a gourd which grows well on the Shansi highlands are eaten. Small quantities of bean curd are also eaten by those who can afford it.

For cooking the fried portion of the diet, sesame oil is mainly used and a small amount of hemp oil.

In order to make matters certain on the question of food and its relation to the disease, one of us (Miles) on two occasions spent a month in Pingtingchow working at this subject. On the first occasion (in 1923), although one obtained reliable blood estimations from 10 patients, it was found to be impossible to be sure of the accuracy of the analyses of the urine, fæces, and food. So a second trip was made in 1924, and on this occasion he was accompanied by a skilled chemist, Mr. C. T. Feng, of the Union Medical College, Peking, who is also an able Chinese administrator. We had previously learned the quality and quantity of the food which these patients were getting. Four cases, which were active, were chosen for the investigation and admitted to the hospital free of charge. And here the first difficulty was met. These women knew that they were in for investigation, and at our expense, and that we could cure them by medicine, and they wanted better food than they got at home. Finally, a satisfactory compromise was come to; and the diet which they got, although a little better than the normal one, was still sufficiently near it to make the test a real one. The patients were allowed as much as they liked to eat, and this was measured for a day or two. Then measured quantities were served out to them, so that they would consume all that was given, and the urine and fæces were carefully analyzed. This went on for 14 days, and then, after a few days' rest, they were put under treatment continuing the same diet for another 14 days, whilst under the influence of the treatment. The results of the treatment and analyses are given below.

First let us take the table which represents the more valuable results of the first year's work.

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TABLE III.

Patient Number	Blood Calcium in mg. per 100 cc. serum.	Blood Phosphorus in mg. per 100 cc. plasma.	CO_2 combining power of plasma reduced to 0°C & 760 mm. pressure
1	5.2	2.5	51.3
2	6.0	1.9	57.0
3	7.4	1.8	47.5
4	5.6	2.3	54.1
5	5.8	3.0	51.3
6	7.0	3.8	54.1
7	5.8	3.4	52.2
8	7.0	2.4	49.4
9	5.0	2.0	54.0
10	5.4	3.2	56.0

It will be seen that there is a marked deviation from the normal calcium content of the serum, this being in some cases less than half the quantity considered as normal, and in the highest determination being only about three-quarters of the normal. The phosphorus in the blood varies greatly, some of the patients showing a marked deficiency while others come within normal limits.

The degree of variation from the normal in blood calcium and phosphorus seem to depend directly on the severity of the disease and its duration. Salient points in the histories of these patients, together with their pelvic measurements, are presented in Table IV. It will be seen that in the three patients 3, 6 and 8, in whom the disease had been present one year or less, the calcium content of the blood and the phosphorus content of the blood is more nearly normal than in any of the others, and also that the degree of pelvic deformity is not so great. Further, it is revealed that, while most of the patients had symptoms first during lactation, two of the patients had never been pregnant, in one of whom the symptoms came on about the menopause; another had two early abortions before the fœtus could have caused a severe calcium drain; and in another the disease began at the onset of the menstrual function. The menstrual flow in these patients was uniformly scanty and the cycle irregular. It would, therefore, seem that the added drain on calcium due to pregnancy and lactation is not an absolutely essential factor in producing the disease, and though it undoubtedly may play a part, it is not the sole cause. Nor does it appear that the function of the ovaries or the menstrual function play a

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major *rôle*, as in all of these patients the ovarian function is faulty, as evidenced by scanty menstruation and irregularities in the menstrual cycle.

TABLE IV.

Patient	Age	Duration of Disease	Number of Pregnancies	Relation of onset of disease to pregnancy	Tetany	Pelvic Measurements				
						Inter-spinous.	Inter-crystal.	External conjugate.	Inter-ischial.	Inter-trochanteric.
1	23	5 yrs	None	None	No	24	26	18.5	2.5	25
2	57	10 "	None	None	Yes	22	25.5	18	3.0	23.0
3	30	8 mos.	2	During last lactation	Yes	23	24	17	7.0	25.5
4	34	20 yrs.	5	Began before 1st pregnancy at onset of menstruation.	Yes	20	23	21	3.0	22.0
5	32	12 "	2	After first delivery	No	20	25	17	2.0	24
6	35	1 year	5	During last lactation	Yes	22.5	26.5	20.5	6.0	30
7	25	7 yrs.	3	During first "	No	21	25.5	19	2.0	22
8	19	1 year	1	During lactation. Pregnant 3 mos. on admission. Marked exacerbation of all symptoms. Aborted in hospital	Yes	19	23	19	9	29
9	37	9 yrs.	2 abortions	None	Yes	21	27	19.5	3	29
10	24	6 "	3	During first lactation	Yes	--	--	--	--	--

After completion of the blood analyses on the standard diet nine of these patients received treatment as follows, remaining on the same food: Patients numbers 1 and 4 took cod liver oil 30 cc. and calcium lactate 2 grams per day; patients numbers 2 and 3 had calcium phosphate 3 grams per day; patient number 5 had calcium lactate grams 2 per day; patients 6 and 8 were placed on a liberal diet including milk, eggs and plenty of fresh vegetables; patients numbers 9 and 10 took 30 cc. of cod liver oil per day. Patient number 7 left the hospital at the end of the first period. After the patients had received this treatment for 12 days the blood was again analyzed for calcium and phosphorus, and the results are presented in Table V.

It will be seen that the four patients to whom was given cod liver oil, either alone or with calcium salts added, all show a net gain in blood calcium as compared with the results of the first

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TABLE V.

Patient	Blood Calcium	Blood Phosphorus in mg. per 100 cc. plasma
1	6.0	2.61
2	5.8	2.9
3	8.7	1.0
4	6.21	3.5
5	7.7	2.3
6	4.6	4.1
8	6.6	3.57
9	6.6	2.95
10	7.57	1.95

estimation; those receiving calcium salts with no oil also showed an increase in blood calcium in two cases and practically the same amount in the third case as in the first estimation; the two patients on liberal diet both show a decrease in blood calcium content. The phosphorus content of the blood seems to vary with no regularity.

The clinical results were also suggestive in that the four women who were treated with cod liver oil, alone or combined with calcium lactate, said that they were much improved and that their pains were less even after such a short treatment, and we observed that these patients moved about the ward and took more interest in life than they formerly had. Patient number 2, who took only calcium phosphate, was decidedly worse, complained more of pain and could hardly move. Patients number 6 and 8 on liberal diet were both clinically worse than at the beginning of the experiment. As these women were both suffering from an early acute attack of the disease, the result is not strange and in addition patient number 8 had a spontaneous abortion of three months' fœtus and did not take her diet well after that occurred.

As has been already said the first year's work was not entirely satisfactory, and so the second year's work was undertaken.

Ten patients were found to be too many to manage satisfactorily and so four patients were chosen. Full details of those patients are given in Miles' paper and the results are here summarized only. They were all marked cases of osteomalacia with deformity, and the salient points are given in the following table :—

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TABLE VI.

Patient	Age	Duration of Disease	Onset	Pregnancies	F.H.	Tetany	Pelvis	Chest
1	31	12 years	1st pregnancy	6 2 living first & last Caesarean section	Mother had Osteo-malacia	Yes	Seriously deformed	Deformed
2	29	6 years	1st puerperium	1 Child died after a year	No	Yes While in Hospital	Seriously deformed	Moderate deformity
3	37	15 years	1st pregnancy	5 1st two living. Last 3 still born	No	Yes	Seriously deformed	Moderate deformity
4	49	8 years	No pregnancy	---	One sister	No But reflexes exaggerated	Seriously deformed	Deformed

These four patients were put on the following diet, which approximates closely to their normal diet when at home :—

TABLE VII.

Average daily ration

Breakfast
133 grams of wheat flour in the form of steamed bread
50 grams of millet in gruel
10 grams of salt turnip

Dinner
150 grams of wheat flour made into a thick dough, rolled thin and baked
170 grams of Chinese celery cabbage
8 grams of garlic (boiled together)

Supper
100 grams of wheat flour
30 grams of green soy bean flour rolled into noodles and boiled
40 grams of mustard leaves and stalks
8 grams of garlic (boiled together)

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It may be asked: What is the caloric value of such a diet? The protein amounts to approximately 25 grams per day. Fat (allowing a little sesame oil used in frying) is 10 grams per day. Carbohydrate amounts to approximately 337 grams a day. This gives a total caloric value of 1587.7 per day. It is a little lower than one of us (Miles) estimated in the paper specially written on these experiments, but is probably more accurate.

The figures for the various foods, kindly given us by Miss Huang, the dietitian at the Peking Union Medical College, are as follows:—

TABLE VIII.

Chinese foods used in Osteomalacia experiments.

Percentage Composition

	Prot.	Fat	Carb.	Calories
Wheat flour	10.8	1.1	74.8	352
Bread white	9.2	1.3	53.1	261
Millet	9.2	.2	76.6	354
Pai tsai (Chinese Celery cabbage)	1.16	.05	2.5	15
Turnips, Chinese, fresh	.63	.01	5.62	25
Mustard stalks, see below				
Cabbage	1.6	.3	5.6	32
Soy bean	36.71	17.43	24.93	403
Onions	1.6	.3	9.9	49
Sesame oil, approximate fig. by Mr. Cameron	----	90.0	----	810

Whereas there are no figures for Chinese Mant'ou and mustard stalks, figures for White bread and Cabbage might be used in their places, respectively.

Numerous samples of these foods were selected and carefully analyzed.

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Here are the percentage proportions of calcium and phosphorus in the food given :—

TABLE IX.

	Wheat Flour	Millet	Bean Flour	Garlic	Cabbage	Mustard	Salt Turnip or Radish
Calcium %	0.07415	0.07664	0.10705	0.042	0.03525	0.1896	0.1214
Phosphorus %	0.3295	0.3349	0.3828	0.02024	0.0431	0.0386	0.060

In Table X. we see the amount consumed by each patient in seven days, with the total phosphorus and calcium content of the same :—

TABLE X.

Patient	Wheat Flour	Millet	Bean Flour	Cabbage	Garlic	Mustard Leaves	Salt Turnip	Total Ca.	Total P.
1	2681	350	210	1190	110	280	70	3.5630	11.4857
2	2331	350	140	1190	110	280	70	3.2285	10.0657
3	2681	350	210	1190	110	280	70	3.5630	11.4857
4	2331	350	140	1190	110	280	70	3.2285	10.0657

Shohl and Sato estimate that the daily calcium requirement of the average person *per* kilogram of weight is 0.0152 gm. in order that he may remain in a state of calcium balance. Ehrstrom considers that the minimum phosphorus pentoxide required by an individual is 0.06 gm. of P_2O_5 *per* kilo daily, or 0.0261 gm. of phosphorus *per* kilo daily. Based on these figures Table XI. presents the daily consumption of calcium and phosphorus in grams, and also the quantities of both required daily by the patients according to their respective weights. The diet as given, though undoubtedly more liberal than their home diet, is still deficient in calcium, though adequate in phosphorus.

TABLE XI.

Patient	Intake of Calcium per day	Daily required Calcium.	Daily Diet balance Calcium	Intake of Phosphorus per day	Daily required Phosphorus	Daily Diet balance Phosphorus
1	0.5090	0.53244	minus 0.0234	1.6408	0.9282	Plus .7126
2	0.4612	0.4758	minus 0.0146	1.4365	0.8117	" 0.6248
3	0.5090	0.6548	minus 0.1458	1.6408	1.1170	" 0.5238
4	0.4612	0.4666	minus 0.0054	1.4365	0.7960	" 0.6405

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The fæces and urine were very carefully collected, weighed and analyzed. The results are shown in the following tables:—

TABLE XII.

Patient	Total Ca. in gm. urine 7 days	Total P. in gm. urine 7 days
1	1.6351	2.8598
2	0.2634	1.9879
3	0.3467	3.2646
4	0.6606	2.7657

TABLE XIII.

Patient	Total Ca in gm. faeces 7 days	Total P in gm. faeces 7 days
1	2.4213	5.7847
2	3.0145	4.4503
3	2.7761	5.7758
4	3.4104	5.7543

Having estimated these figures, a table was drawn up which represents the position of the patients as regards the calcium and phosphorus balance.

TABLE XIV.

		Calcium in grams		Phosphorus in grams		
Patient	Intake	Excretion	Bal. 7 days	Intake	Excretion	Bal. 7 days
1	3.5630	4.0564	Minus 0.4934	11.4857	8.6445	Plus 2.8412
2	3.2285	3.2779	Minus 0.0494	10.0657	6.4382	Plus 3.6275
3	3.5630	3.1228	Plus 0.4402	11.4857	9.0404	Plus 2.4453
4	3.2285	4.0710	Minus 0.8425	10.0657	8.5200	Plus 1.5457

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To complete the series the blood calcium was also estimated and the result is shown in Table XV.

TABLE XV.

Patient	Calcium in mg. per 100 cc. serum	Phosphorus in mg. per 100 cc. plasma
1	7.503	1.83
2	6.395	1.24
3	6.175	2.42
4	5.810	1.55

It thus was evident that three out of four of the patients were in a condition of negative calcium balance, whilst all had a positive phosphorus balance.

Is the negative calcium balance merely the expression of a calcium deficiency in the diet, or is it that the diet lacks some element which acts as an activator in the retention of calcium?

It will be noted that patient 3 had a positive calcium balance. She was an old patient of the hospital and had received two short courses of treatment with cod liver oil and calcium phosphate, the last of which was in the fall of 1923, about four or five months before this experiment was begun. She was so much improved that she asked to come into the hospital on the "metabolism squad." Physically, she was the most active of the four patients. Tso has observed in rickets that, even after a short course of treatment by cod liver oil, the X-ray shows bone development proceeding for as much as two or more months after cod liver oil has been discontinued. This probably accounts for the behaviour of this patient in regard to her calcium balance.

Having thus determined the actual condition of affairs the patients were put on treatment as follows:—

1. Cod liver oil 8 cc. three times a day. Same diet. (See Table VII.)
2. Cod liver oil 8 cc. three times a day and 1 gramme calcium lactate. Same diet.
3. Cod liver oil 8 cc. three times a day and 1 gramme calcium phosphate. Same diet.
4. Olive oil 8 cc. three times a day and 1 gramme calcium lactate. Same diet.

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The results are shown in the following table :—

TABLE XVI.

Patient	Total Calcium in gm. ingested - 7 days	Total Phosphorus in gm. ingested - 7 days
1	3.5811	11.4983
2	4.4083	10.0783
3	5.4881	12.3195
4	4.4083	10.0783

The excretion in urine and fæces is shown in the next tables :

TABLE XVII.

Patient	Total Ca. in gm. Urine - 7 days	Total P. in gm. Urine - 7 days
1	1.4034	2.8440
2	.8276	2.0445
3	.4157	2.9627
4	.6638	2.5875

TABLE XVIII.

Patient	Total Ca. in gm. Faeces - 7 days	Total P. in gm. Faeces - 7 days
1	1.9801	5.6582
2	1.9445	2.6911
3	1.7854	3.2528
4	4.2530	4.5855

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Taking these results, the position of the patients as regards the calcium and phosphorus balance was again estimated :—

TABLE XIX.

		Calcium in gm.		Phosphorus in gm.		
Patient	Intake	Excretion	Bal. 7 days	Intake	Excretion	Bal. 7 days
1	3.5811	3.3836	Plus .1976	11.4983	8.5022	Plus 2.9961
2	4.4083	2.7712	Plus 1.6371	10.0783	4.7356	Plus 5.3427
3	5.4881	2.2011	Plus 3.2870	12.3195	6.2155	Plus 6.1040
4	4.4083	4.9168	Minus .5085	10.0783	7.1730	Plus 2.9053

The blood calcium and phosphorus results at the end of seven days are given in Table XX.

TABLE XX.

Patient	Calcium in mg. per 100 cc. serum	Phosphorus in mg. per 100 cc. plasma
1	8.62	1.83
2	8.197	2.10
3	9.57	3.02
4	8.58	1.64

Discussion.

For the sake of clearness the cases will be taken up in order, and the results of the two experiments will be compared.

Patient No. 1.—On an identical diet with that used in Experiment 1, which was deficient in calcium; but with the addition of cod liver oil; her calcium balance changed from a negative to a positive one and her blood calcium from 7.503 mg. to 8.62 mg. per 100 cc. serum. The weekly calcium output in the urine was very high in both experiments, but in the second the output in the urine and fæces was less than in the first experiment, which

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accounts for the change in the balance and for the increase in calcium in the blood. The change in the phosphorus balance was very slight, and there was no change in the blood phosphorus. It would seem from this experiment that there must be in the cod liver oil some element which in osteomalacia will materially influence the retention of calcium in the system even in the presence of a deficiency in the food. Clinically, she was greatly improved. On admission she would not leave the bed, and sat with her head supported on a Chinese pillow about which she held her arms, but at the end of the second experiment she was voluntarily leaving the bed for a chair, and would walk the length of the ward, though it was slow work.

Patient 2.—With the standard diet and cod liver oil and calcium lactate added, the calcium balance changed from a slightly negative to a marked positive. The calcium in the urine increased in the second experiment, but in the fæces there was a decrease as compared with the first experiment. The blood calcium changed from 6.295 mg. to 8.97 mg. The phosphorus balance was more strongly positive than in the first experiment, and the blood phosphorus increased from 1.24 mg. to 2.10 mg. She was clinically much improved.

Patient 3.—Calcium phosphate and cod liver oil added to the diet made even more marked changes. The calcium balance changed from plus .4402 gm. to plus 3.2870 gm., and the phosphorus from plus 2.4453 gm. to plus 6.1040 gm., and the blood calcium and phosphorus were profoundly affected. The calcium phosphate containing more calcium in the molecule than the lactate, she got a correspondingly greater amount of calcium, and it also contains the phosphorus. In this case again we found the calcium in the urine increased and in the fæces decreased in the second experiment. In these two cases we see a magnification of the effect of some element in the cod liver oil observed in Case 1. In both cases we now have no deficiency of calcium in the diet, and the activator enables the patient to utilize and retain larger amounts of calcium than in the first case. The retention of the calcium calls for a corresponding retention of phosphorus which we find in the increase in the balance ratio and also in the blood.

Patient 4.—This patient was given, in addition to the regular diet, olive oil 8 cc. and 1 gm. of calcium lactate daily. The olive oil was given because the other patients were getting oil and we did not want this patient to feel that she was treated differently from the others, also from numerous other experiments we felt that over so short a period the olive oil would probably produce no effect on the calcium metabolism. We found that her calcium balance remained negative, though to a less degree in the second

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experiment than in the first; the calcium excretion in the urine remained almost stationary, with a big increase in the calcium excreted in the fæces, a reversal of the condition in the others. The blood calcium was increased almost in proportion to the others. This must mean that the calcium is absorbed from the intestine and goes to increase the blood calcium, but unless utilized in the tissues is returned to the digestive tract and is excreted. The change in the balance of calcium and the increase in blood calcium are probably due to temporary storage of calcium in the blood and not to metabolized calcium. The blood phosphorus remained practically stationary, with a small change in the total phosphorus balance. Clinically she did not improve and complained that the other women wished to move a little while she did not.

Taken together we see that in these patients with osteomalacia there was a deficiency of calcium in their diet. This may have an effect in producing the disease, but there is another deficiency in their diet which is of greater importance than the calcium, namely, the vitamine content, whether "A" or "X," which is found in cod liver oil and other animal fats. Increasing the calcium in the diet of Case 4 did not clinically improve her condition and did not produce an absolute positive balance. Yet in Case 1 without an increase in the calcium and only the addition of the cod liver oil she improved clinically and also retained and utilized calcium. In Cases 2 and 3, with the two deficiencies in the diet made up by the addition of calcium salts and the cod liver oil, the changes were correspondingly marked.

Three facts at once became clear:—

(1) These women are living on the edge of a calcium starvation diet, and probably in the circumstances prevailing in their own homes are at times actually calcium starved.

(2) Although the administration of vegetable oil with the diet in one case led to a rise in the blood calcium, it did not appear from the figures to be more than a piling of calcium into the blood to have it promptly cast off again, for the negative balance was not transformed into a positive balance.

(3) That the addition of an activator in the form of cod liver oil at once led not merely to a rise in the blood calcium but to the transforming of a negative balance into a positive one, showing that the calcium was not merely being carried into the body, but that the body was using the same for anabolic processes.

What is the process which is going on which in the absence of a sufficient activator leads to the calcium loss and the appearance of symptoms?

B. E. Read, of the Peking Union Medical College, has urged on us the view that for some reason or other, largely due to the

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character of the food, the acid base equilibrium of the body is upset. These diets produce an acid ash, and this leads to the washing out, so to speak, of the body calcium, and instead of the calcium of the food being absorbed, the acids formed by this food combine with the calcium to form salts and are thus excreted. The final result is a calcium starvation plus a calcium drain, and this occurring in pregnancy, proves too much for the stability of the body supply, and leads to the bones being called on in an abnormal manner to supply the general deficiency.

Our own work does not tend to bear out this theory. In the first series of Miles' Shansi experiments the carbon dioxide combining power of the plasma does not seem to indicate a change in the acid-base equilibrium and the results do not indicate an acidosis.

E. W. H. Cruickshank, of the Peking Union Medical College, in a personal communication, says :—

"It is a very difficult thing to alter the acid-base balance, so difficult in fact that in acute tetany with alkalosis due to a marked CO_2 deficit, the alteration in pH may vary by only 0.15 to 0.20, and this variation is quite within physiological limits.

The idea of the acid ash denoting an acid diet, acid enough to upset the buffer action of such a physico-chemical system as blood, needs to be viewed with caution.

The question of what leads to a washing-out of body calcium is a very complicated one. It depends upon the form in which calcium is most easily excreted by the bowel and kidneys. Is that form a salt or an ion? There is a distinct relationship in an *in vitro* mixture between Ca^{++} HCO_3^- and H^+. If the formula of Rona Takahashi holds in blood, then any increase in H ion concentration will favour the increase in Ca ions and Ca ions can readily get out by the kidney, and this is favoured by lack of parathyroid or protein poisons. What part, if any, does fat soluble vitamine play in controlling the amount of Ca ions, which may be liberated from or taken up by protein or salts? H ion concentration plays a part, we are sure, in controlling the union of Ca with protein of tissue just as it plays a part in controlling the union of Hb with K and with O_2. But with a process of metabolism; to say that is only one step nearer home, in that it gives an inkling to the part a vitamine may play. And as Mellanby suggests, high protein foods may be playing a part antagonistic to the normal anabolic processes.

As far as the work we have done goes, it tends to show that parathyroid lack alters the balance between ionic and colloidal calcium. Most of the Ca goes to the ionic form and with that change there is a change in pH to acid side of neutrality, and here one is back to the experimental *in vivo* proof of the *in vitro*

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relationship between H ion, Ca ion and HCO_3 ion. It may be that parathyroid extract is the correct key for the treatment of the tetany of Ca breakdown; whilst a supply of fat soluble vitamine is the key for the treatment of the osteomalacic disaster; if so, the pathological change in protein chemistry is different, though not necessarily essentially so."

These ideas naturally lead on to the consideration of two questions, neither of which we are able to answer definitely, but both of which deserve careful consideration.

Is the setting up of a process of this kind, if it really occurs, due to the protein of this ill-balanced diet? Mellanby has brought forward evidence to prove that cereals in a diet which is deficient in fat vitamine tend to produce defective bone calcification, and apparently it is the protein element, which is the responsible factor. Moreover, a diet of this kind in puppies tends to produce muscle changes and weakness of locomotion. In the osteomalacia cases in goats, which I shall mention later on, there was undoubtedly overfeeding with beans, which contain a high protein factor.

Is there a definite shortage of fat soluble vitamine in these diets? There is undoubtedly in the Shansi cases (especially at times) a very poor supply of green vegetables, which is the main source of their fat soluble vitamine in the absence of milk, butter, eggs and animal fat. That there is not a gross shortage is pretty certain, as, in spite of careful inquiries, we have not been able to trace any cases of zerophthalmia, but the rapid improvement which takes place on the administration of cod liver oil proves that there must be a shortage in this direction granting that the activator is really fat soluble vitamine, and not a special substance found *par excellence* in cod liver oil.

How does this activator act?

There is no doubt that fats play a large part in the transference of mineral salts from the bowel to the blood, but, as we have already said, vegetable fats will do this to a sufficient extent and yet fail to meet the situation. Vines and Cruickshank have brought forward evidence to prove that the parathyroid gland has a profound influence on calcium metabolism in the body, and Erdheim has reported pathological changes in this gland in five out of six cases of osteomalacia, but it is not clear that these changes may not be the effect of the osteomalacia rather than its cause; and although our experience so far with the administration of the commercial gland-products has been small, we have seen no results which would justify our saying that the administration of this gland plus cod liver oil is more efficacious in the cure of the disease than cod liver oil alone.

We think there is little doubt that infections added to the

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disease aid its progress. In our sole case of osteomalacia in the male, the process apparently started at the age of 12, as a sequel to an attack of measles, combined with close confinement to a dark room for many weeks; and thereafter there was an intensification of this treatment—*i.e.*, confinement to a dark room and bed, due to the pain accompanying the onset of the disease and sepsis due to bed-sores. But we have no evidence which would justify our placing this disease in the category of microbic infection. The work of Montpurgo and others in Italy, and Mossu and Charrin in France, as to a definite infective agent which is transmittable, needs confirmation, and is doubtful in view of the other facts which we know about the disease.

What influence has the environment factor on the genesis and progress of the disease?

In Shansi, where the disease is most prevalent, the "Kangs" are heated by coal, the fumes to a considerable extent escaping into the room, and this means pollution of the atmosphere. Cases of carbon-monoxide poisoning are not by any means unknown. Next there is the evil influence of foot-binding, in retarding health and preventing movement. Following this one has the fact that these cases are mostly occurring on the uplands, where the winters are severe and confinement to the house, especially in the case of women, is almost complete. And in considering the movement factor one has to note the significant fact that osteomalacia is a disease of the middle classes. The poor, who are compelled to get out and work in the fields, rarely get it. The rich, who have plenty of nourishing food, with meat and fat, are seldom affected. The victims are what we might almost call the genteel members of Society; too proud to work, even if their families would allow it, not rich enough to afford the meat and fat which would correct the deficiency in other ways.

As was mentioned earlier on in this paper, after the close of Miles' Shansi experiments, we received the paper on two cases of infantile tetany which had come into the medical wards of the Peking Union Medical College. Looking at the blood estimations it was clear that we had here a parallel case to our Shansi work. If this was correct these girls ought to have signs of commencing osteomalacia. They were fetched back to hospital and re-examined with the result that both of them showed signs of the disease.

It is interesting to note a few facts about this Orphanage. It contains about 50 girls and 70 boys from 10—18 years of age. No boys presented signs of tetany, but of the girls, who remained mostly indoors during the winter months, there were no fewer than 10 who complained of "ma mu," and some had facial phenomena showing that they had either had tetany or were on the verge of it.

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The diet at this Orphanage is as follows:—

Breakfast: Millet gruel, corn bread, salted carrot.
Lunch: Wheat bread, vegetable.
Supper: Corn bread, vegetable, salted carrot.
Meat once a month.

Vegetables are as follows, according to the season:—

Cabbage—October to January.
Bean sprouts—February.
Onion and bean curd—March.
Spinach—April.
Egg plant and gourd—May to August.
Pearl melon—August to September.

It also has to be borne in mind that children have their likes and dislikes, and will pick and choose their food, thus possibly helping on a diet deficiency trouble.

Finally, there is the question of sunlight. Some of the small courts get little, and if the woman stays on the "Kang" (and she tends to stay there more and more after the pains of the disease come on) she gets very little sunshine. So that, taken altogether, the environment certainly aids the disease.

As bearing on the general question of the ætiology of this disease, it must also be borne in mind, *first*, that it is extremely rare when an adequate diet is in vogue among any people, and *second*, that an improvement in diet will lead to its speedy disappearance from places where it has formerly been rife.

Whether there is any racial tendency to the disease is doubtful. We have quoted one case in which an Australian woman living under Chinese conditions contracted the disease.

Irving has also personally pointed out to one of us that only three cases of the disease have been diagnosed at the Lying-in-Hospital in the Harvard Medical School during the past ninety years. Strangely all these cases occurred in Syrians, but it is known that in the case which was most carefully studied, the diet was extremely poor, almost a starvation diet.

Our own conclusions as to the ætiology of the disease are as follows:—

Osteomalacia is a diet deficiency disease and is to be placed in the same category as rickets.

The deficiency is principally in the fat soluble vitamine or calcium activator content of the diet, though there may be and probably is an actual or at least a proportional calcium deficiency at the same time.

The result of this deficiency diet is that a disturbance of the normal calcium metabolism is set up, and it is possible that in

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addition to the diet deficiency there is a toxic process set up by an unbalanced protein consumption (cereal).

Intercurrent septic affections will aid in the progress of the disease, but probably only by lowering the general vitality, and there is no evidence of such infection in the majority of cases.

The evidence suggesting diseased processes in the ovaries and parathyroid is insufficient to place the blame for the disease on either organ.

Osteomalacia may be prevented by improving the diet of the population in the direction of a fuller supply of fat soluble vitamine and salts. It may be cured by providing a sufficiency of food plus a calcium activator such as cod liver oil and sunlight.

Section V.

The Sequelæ of Osteomalacia.

The sequelæ of osteomalacia may be divided into those which affect labour, and those affecting marital relations.

The sequelæ affecting labour have long been known. In fact, wherever there is a hospital in a region in which osteomalacia occurs, the measure of the severity of the disease is indicated by the number of Cæsarean sections. I have no records of any patient in China coming to hospital in whom the pelvis was soft so that it could be opened with the hand. As a rule, it has been a question of craniotomy (if it could be done), or Cæsarean section; and in both the mortality rate for the mother has been very heavy owing to the fact that these cases come in after one, two, three, four, five, or six days' labour, most of them already septic, and often with the vagina seriously damaged and infected.

The native midwives have no idea of how to deal with these patients. They take either a meat-hook and conceal it in their hand, binding it to the wrist; or they take a pair of charcoal tongs and bend over one of the points to form a rough hook. The hand with the hook of the modified tongs is then introduced into the vagina, and anything that can be caught and torn away suffers this fate. Naturally, they produce the most terrible injuries to the bladder, bowel and vagina. I know of one case in which the uterine wall was torn and part of the maternal bowel dragged down and torn out; and I know of more than one case which has entered hospital with the uterus ruptured, whilst vesico-vaginal fistulæ are common in the few cases that survive this sort of manipulation.

What is the best treatment for cases with contraction due to osteomalacia? If the contraction is at all severe, provided the patient is seen before labour or early in labour, Cæsarean section with tying of the Fallopian tubes to prevent a further pregnancy is

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the method of choice unless the patient wishes to have another child. Unless the case is a really severe one, it is quite safe for her under appropriate treatment to risk another pregnancy without fear of the disease becoming again active.

The best method of dealing with the Fallopian tubes is the following: Double ligature the tube about one inch away from the uterine cornu. Divide between the ligature; with the points of a pair of fine pressure forceps make a small tunnel on the back or front of the uterus, as is most convenient, under the peritoneum. Draw the uterine end of the tube into the tunnel, and fix it there by a fine stitch. This is easily done, and makes a further pregnancy impossible. The question of the method of Cæsarean section which should be used in these cases is not fixed, probably a two-flap extra-peritoneal section is the best.

In the very neglected cases there is no doubt that the safest method is a Cæsarean hysterectomy.

Should the contraction be a moderate one and the child be dead, a craniotomy should be done, and a Cæsarean section planned for the next occasion.

As to the anæsthetic to be used, chloroform is very dangerous in these neglected cases. Ether should be used. Open ether with a preliminary injection of atropine 1/200 grain (no morphine) is the best form of exhibiting the anæsthetic.

With regard to the question of marital relations, in quite a number of cases the tubera ischii become almost apposed, so that one cannot get a finger between them. Then the inclination of the pubes becomes altered, and the descending rami of the pubes and ascending rami of the ischia are approximated so that coition becomes impossible. When there are several wives this is not a matter of such importance, but when the patient is the only one, the result may be a most miserable home. The following case may serve as an illustration.

Case No. 3062. Lo Yin Shih, aged 26; from Shou Yang, Shansi, came into the Peking Medical College Hospital on September 5th, 1922. Patient was married at 16 years of age. When she was twenty years old her first child was born naturally; it died when 3 years old. A year later her second child was born naturally, and it died when 3 years old. In the case of both these children the cause of death was unknown.

The third child was born when she was 23 years old and died the day after birth, labour being very difficult. After that time marital relations became increasingly difficult till at last they were impossible. Her husband sold her off to a second man, who finding coition impossible was preparing to sell her to a third. She threatened to commit suicide if nothing could be done for her.

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Dr. F. J. Wampler of Pingtingchow kindly sent her in to me (Maxwell).

Patient's height was 4 feet 10 inches. Weight 92 lbs. Pelvic measurements as follows; spines 21 cm.; crests 23.25; trochanters 22.5 cm.; ext. conjugate 17.5 cm.; interischial 2.0 cm.

A finger could be got into the vagina with difficulty before and behind the tubera ischii. Coition is manifestly impossible. The Wassermann reaction was negative and otherwise the patient was in good health.

Two courses were open: (1) to excise the descending ramus of the pubes, ascending ramus of the ischium, and part of the ischial tuberosity, on one or both sides; (2) to excise the coccyx, and try to make a vaginal opening posterior to the tubera ischii. In the former operation there was the possibility of disturbing the balance of the pelvis and weakening the adductor muscles of the thigh. In the latter operation although one might get a larger vaginal opening posterior to the tubera ischii, yet the direction of the vaginal canal would be displaced very seriously. It was decided to try the first course.

The X-ray report of the pelvis was as follows: "The bones are a little thinner than normal, and it is noteworthy that this thinning is at the expense of the material between the lines of cancellous tissue, so that the cancellous structure stands out very plainly against the darker background. The first portion of the sacrum is very prominent. The pelvis is contracted and the pubic bones project sharply forward so that the symphysis lies well anterior to the descending ramus of the pubes."

On September 14th, 1922, the patient was anæsthetized with ether and placed in the lithotomy position. The site of the operation had been thoroughly painted on the previous evening with brilliant green and crystal violet paint, and a fresh coating was given when she was on the table.

The vulval aperture and the anus were both closed by fine silk. An incision extending from the pubes to below the ischial tuberosity and about four inches long was made about two inches outside the vulval aperture on the left side. The tissues were divided down to the bone, and a superiosteal resection of the descending ramus of the pubes and the ascending ramus of the ischium and half of the ischial tuberosity was made, bleeding points being carefully secured as cut. There was comparatively little bleeding. The vagina was not opened. Care was taken not to interfere with muscular attachments more than was absolutely necessary, and the wound was sewn up with fine silk, bringing the tissues together in their various layers so as to leave no dead

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space. After sealing the area round the wound with collodion and gauze, the vagina and anus were again opened.

The patient made a normal convalescence, and on discharge two fingers could be easily inserted into the vagina, and she had no difficulty in walking. She was seen about three months later. Locomotion was perfect, and it had been possible for her to resume marital relations without any pain or inconvenience.

The subsequent history of the case is very interesting. Within two months she became pregnant. Before operating on her, I had explained the situation very clearly, and she knew that a Cæsarean section was necessary. But coition had been so easy that her relatives, especially on the mother's side, refused to believe that labour could not be conducted in the ordinary way. In spite of my pleadings and protests they refused to send her to hospital, and it was only after she had been three days in labour that they brought her begging for assistance. She was taken to Pingtingchow Hospital under a heavy dose of morphia, the fœtal heart just audible and the uterus already in a state of tonic contraction. Dr. Wampler performed a Cæsarean section. The fœtus, a full time male, was dead, and the mother was desperately ill for 48 hours, but recovered after a smart attack of sepsis. The Fallopian tubes were tied, but the uterus was not removed.

As to the condition of the parts, the vagina admitted two fingers easily. There had formed a hard, irregular crescentic band with the concavity inwards in the situation where the bone had been removed. Locomotion was perfect and there was no instability of the pelvic girdle.

So that, as far as the final result was concerned, the operation had been a complete success; and there would have been but for the stupidity of the relatives, a living and perfect child. In the early months of pregnancy she had been treated with cod liver oil and calcium lactate, and there were no signs of recurring osteomalacia.

Section VI.

Treatment of Osteomalacia.

When the question of treatment is discussed one is confronted with two difficulties. The first is the lack of an accurate knowledge of the process whereby calcium is laid down and taken away from the bones, which, if we knew, might guide us to a rational treatment of the disease. At present one is like a person groping in the dark, seeking empirically for some key which will fit the lock. We also know that by giving cod liver oil, and possibly calcium and phosphorus in addition, we can quickly remove the symptoms of tetany accompanying the disease, and also

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remove the worst of the pain. But even here we find that in what is apparently the same degree of severity, the recovery rate is very variable in its rapidity, and one sometimes seems to succeed up to a certain point, and then one's efforts apparently are fruitless for some time in securing a complete cure.

And one of the complicating features, and this makes up our second difficulty, is that the great mass of the population of North China are living, so to speak, on the edge of a precipice. We can safely say that the food ration of the majority of the people is deficient both as regards quantity and quality, especially the latter. If the standard of living as regards food and exercise could be raised, there is not a shadow of doubt in our mind that osteomalacia would become an insignificant problem. But what can be done, when in one of the best ruled provinces of China, with strict laws against foot-binding, the people refuse to give up this senseless and cruel custom. How can an improvement in the living standard be gained when no one, in view of the political unrest, durst invest capital in what would inevitably raise this standard? Flocks and herds, milk and meat, are wanted, and there is no reason why, given peace and justice and security of tenure, one should not be able to obtain these necessaries. The main treatment for osteomalacia is to secure such security of life and property that a higher standard of feeding and a more healthy standard of living may prevent its development.

In discussing this matter one cannot leave out the question of drought and famine. The whole of North China has been deforested, moreover Shansi lies on the edge of the dry belt and flood and drought follow one another with painful frequency. These questions are of national importance, and problems which can only be dealt with by the nation as a whole. If good roads were available so as to make the interchange of commodities more rapid and easy, we might get a sufficient improvement in living standards without the larger questions being solved, and probably the best way to tackle the question would be by road building.

As to the medicinal treatment of the individual case, we have found that cod liver oil in sufficient doses—and by this we mean at least one and a half ounces daily—combined with calcium lactate, 15 grains a day, is the most satisfactory method. Calcium phosphate does not seem to be as efficient. We have tried treatment with parathyroid gland as an additional help, but, as we have already said, without being convinced that it really helped in the progress of the case. Fresh air and sunlight should also be urged, and the patient made to sit out in the sun.

As far as possible the general diet standard must be improved,

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so that the family understands the importance of the balancing of the various articles of food which it may be able to obtain.

In the case of future pregnancies the patient should be placed on cod liver oil and calcium at the beginning of the pregnancy, and this treatment kept up through pregnancy and lactation, care being also taken that the patient gets an improved and adequate diet.

Section VII.

Osteomalacia in Animals.

Does osteomalacia in the lower animals occur in China? It is known to occur in Europe, especially in France, where it is called "cachexie osseuse" or "maladie des pattes"; also in the United States, especially in Southern Alabama and in parts of Mississippi and Florida. In these places it occurs especially in oxen, cows, horses, sheep, goats, swine, dogs, rabbits and cats. It is supposed to be due to a diet which is deficient in calcium.

One set of cases in goats has come under my notice from a herd in Tung-hsien, Chihli, and another case has occurred in a group of goats in Peking itself. In the first set four kids, which were born in February, were fed with milk for three months; and were in good condition. They were covered by an error in July, and went into kid at once. They fed on alfalfa up to the end of October. At the same time they had a supply, twice daily, of equal parts of maize, black beans and wheat bran. From November onwards the food consisted of dry alfalfa, kaoliang leaves, sweet potato vines, leaves of poplar, willow and hwei shu in addition to the mixture just mentioned. The goats began to show signs of disease shortly after the beginning of November and dropped their kids two months later.

None fully recovered till after they dropped the kids, although they were improving under cod liver oil. Three were affected out of the four. Two made a perfect recovery with straightening of the limbs. One made a partial recovery, but was still improving a couple of months later. All were giving good milk at that time. They all have remained well and have gone through another pregnancy without a recurrence of the disease.

Now, in this case we not only have a diet which is possibly deficient in calcium and in the specific substance which is present in green leaves and cod liver oil, but the question of an unbalanced consumption of protein may also be responsible for the initiation of the disease. The special signs of disease were bowing of the legs, and X-rays showed there was a bending, an increased transparency and a slight blurring of the bony structure. There was no definite affection of the epiphyseal ends of the bones.

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General Conclusions.

1. China is at present one of the world centres for the study of osteomalacia.
2. In the special area involved the incidence is from 1 to 3 per cent. of child-bearing women.
3. Whilst its effects are more often shown in pregnancy and the puerperium, it frequently begins about the time of puberty.
4. The disease is one due to a deficiency diet, the principal lack being in a shortage of mineral content and the activator for calcium metabolism.
5. Lack of sunlight and movement are contributing factors in its production.
6. The bones of full time fœtuses from mothers with osteomalacia do not show the signs of rickets, but of osteoporosis. There is, however, a little evidence to suggest that these infants develop rickets more easily than the normal child.
7. The sequelæ of the disease are two-fold—one, deformity of the pelvis, the results of which on labour may be counteracted by a planned Cæsarean section; two, interference with marital relations, which may be treated by a new operation in which portions of the pubes and ischium are resected.
8. The ovaries have nothing to do with the disease, and it is not necessary either to remove them or even to tie the Fallopian tubes, provided that the woman is treated with cod liver oil and calcium, and this treatment is kept up during any future pregnancy.
9. By improving the diet and supplying cod liver oil it should be possible in due time to stamp the disease out. Prevention is the principal thing, and to this end a settled government and improved means of communication are essential.
10. Animals also suffer from this disease, and can be cured by the administration of cod liver oil.

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Fig. 2. Normal standing position of a patient with osteomalacia.



Fig. 3. Side view of severe case showing the sinking of the head into the chest, the curvature of the humerus and the deformity of the chest.



Fig. 4. Back view of the same case showing deformity of the spine.

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Fig. 5. View of a severe case showing marked deformity of the sternum.



Fig. 6. A case of osteomalacia in the male. Front view.

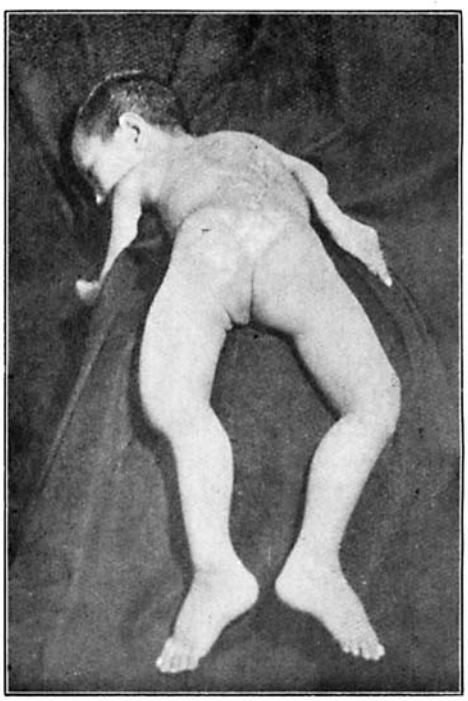


Fig. 7. A case of osteomalacia in the male. Back view.

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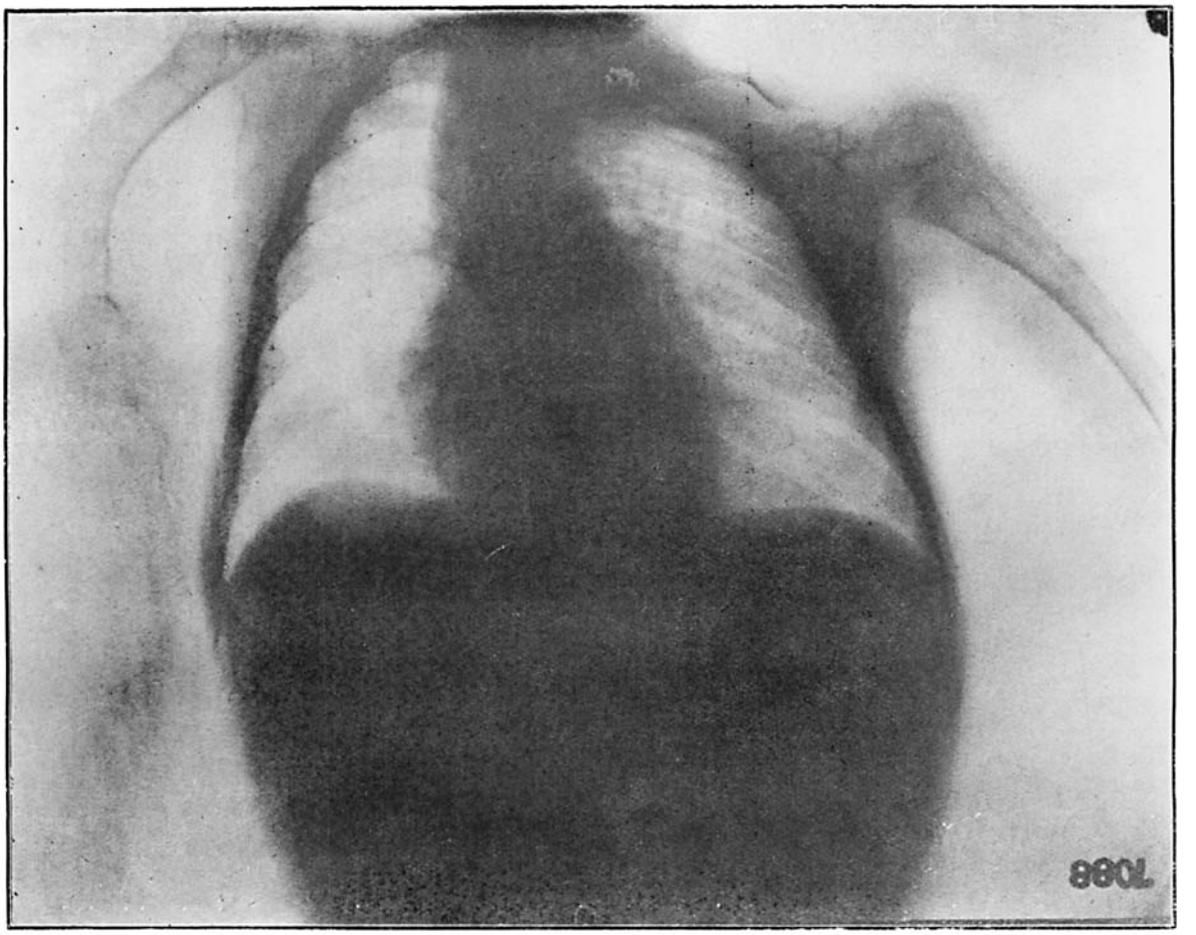


Fig. 8. X-ray of the chest from the case of osteomalacia in the male.

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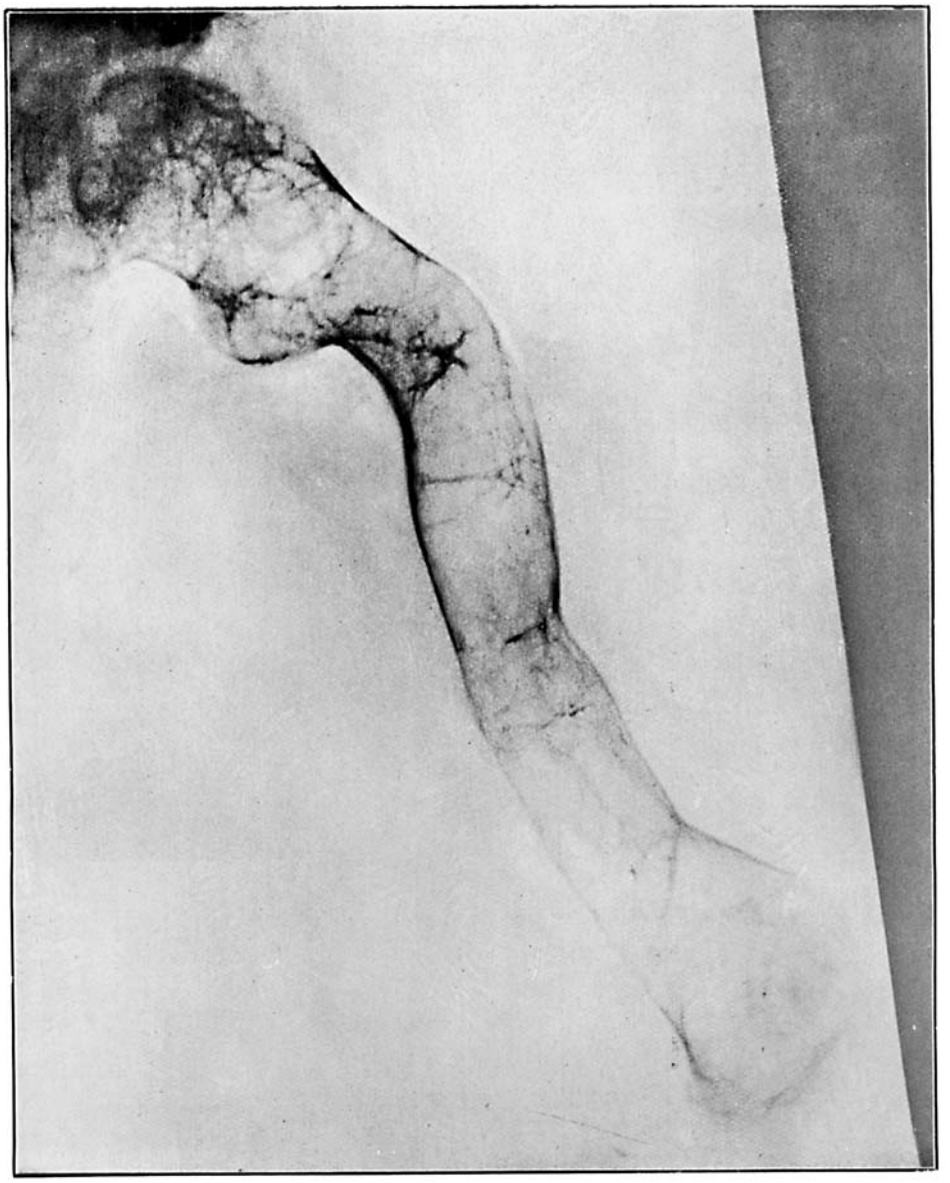


Fig. 9. X-ray of femur from the case of osteomalacia in the male

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Fig. 10. Woman in labour seven days with obstruction due to osteomalacia. Note shortening of figure compared with husband (to the left), son and nurse (to the right).



Fig. 12. Women with osteomalacia with nurse outside the Pingtingchow Hospital. These were the women who came forward for the second portion of the experimental work.



Fig. 11. X-ray of pelvis of girl of 15 who came into hospital for tetany showing commencing deformity of pelvis due to osteomalacia.

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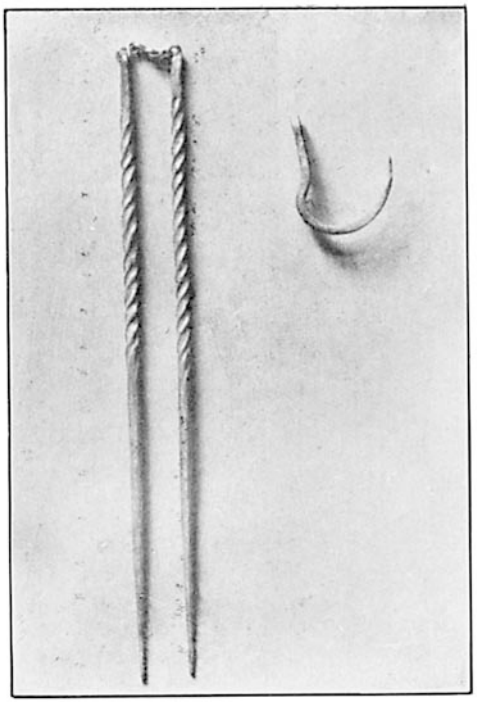


Fig. 13. Instruments used by Chinese midwives in attempting to bring about delivery in cases of labour obstructed by pelvic deformity due to osteomalacia.



Fig. 15. X-ray of pelvis of woman operated on for atresia of the vagina. Before operation.

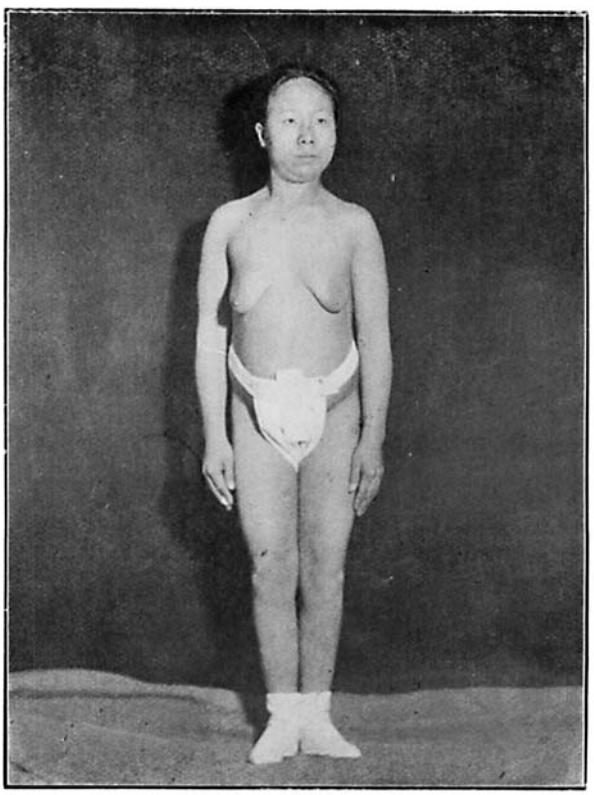


Fig. 14. Woman from Shouyang operated on for atresia of the vagina due to osteomalacia.

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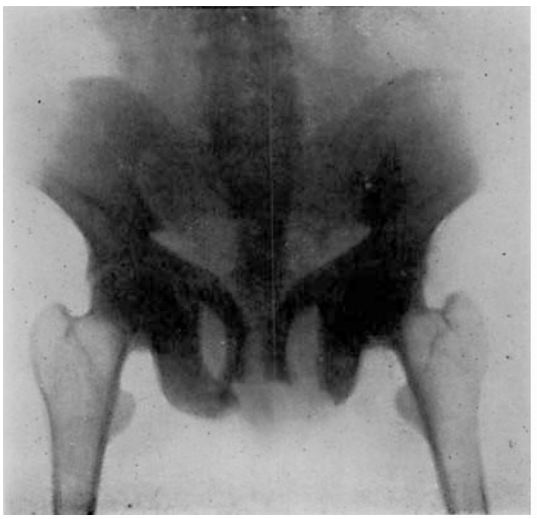


Fig. 16. X-ray of pelvis of woman operated on for atresia of the vagina. After operation.

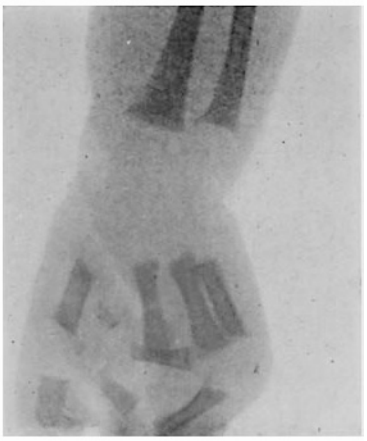


Fig. 17. X-ray of wrist of full-time fœtus from mother with osteomalacia showing cupping of the ulna.



Fig. 18. X-ray of wrist from a second full-time fœtus from mother with osteomalacia showing cupping of the ulna.

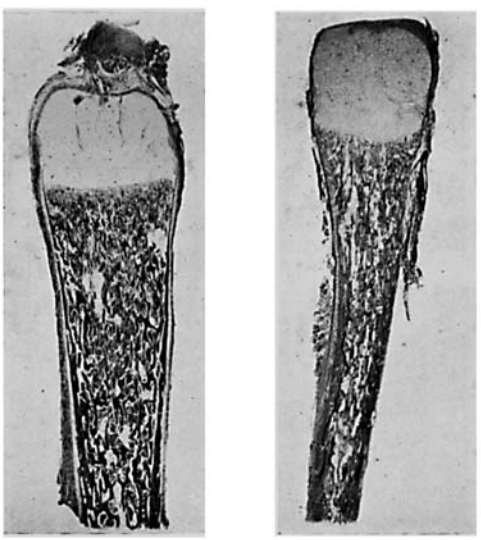


Fig. 19. End of ulna, on the left normal full-time fœtus, on the right full-time fœtus from a case of osteomalacia in the mother.

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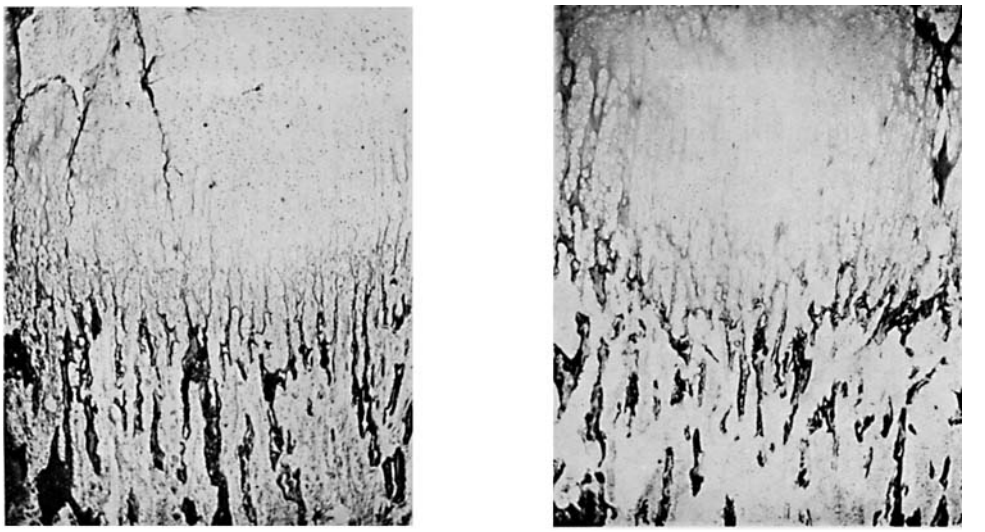


Fig. 20. Microscopical appearances. End of ulna, on the left normal full-time fœtus, on the right full-time fœtus from a case of osteomalacia in the mother.

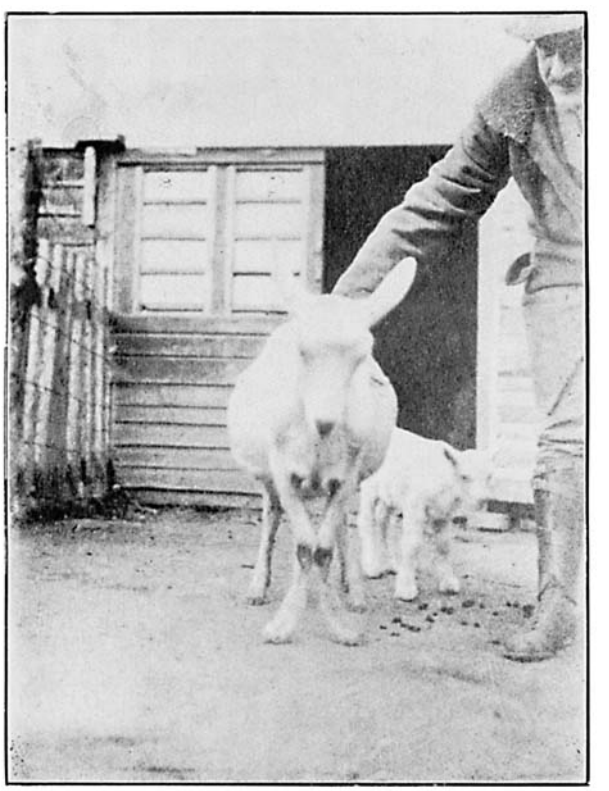


Fig. 21. Osteomalacia in the goat.

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