THESIS

ON

RICKETS WITH SPECIAL REFERENCE

TO MODERN VIEWS ON THE ETIOLOGY AND TREATMENT.

PRESENTED BY

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m. d. 1927.
1. Introduction.

2. Historical Outline.


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MODERN VIEWS ON THE ETIOLOGY OF RICKETS.

Introduction.

Rickets is a disease with which the layman has become conversant during the past few years, and is therefore a subject to which medical men have to turn their attention more often. The Press publishes articles on Rickets, and these articles are read by all classes of people, who expect their doctors to be well informed regarding its causes and cure. This is all to the good.

The present day style of dress for both boys and girls shews up any deformity of the legs, and appearances are nowadays considered so much that parents are anxious to avoid anything which may detract from their children's physique. Further, systematic child welfare visiting is gradually opening the eyes of the people to slight defects, and in those days of clinics of all descriptions, poverty is no excuse for neglect of the health of the child.

Another question of the day is that of Puerperal Mortality, and much dismay is caused by the annual reports on this subject, the Maternal death-rate in Scotland in 1925 being 6.2 per 1,000 births, nor is this figure diminishing/
There is no doubt that Rickets with its associated contracted pelves is a distinct factor in this high rate of mortality, as also in the number of stillbirths.

Within the past six years considerable work has been accomplished in finding the cause of Rickets, the previous ideas of want of lime salts in the water drunk, or in the food taken, or defective hygienic surroundings, though still accredited, have given place largely to the opinion that the disease is due to a deficiency of certain necessary ingredients of food, the Vitamins, the absence of Vitamin A being generally considered as the main factor in the production of Rickets.

Various opinions are expressed as to the incidence of Rickets, Dr. H. Corry Mann in special reports to the Medical Research Council in 1919 - 1921 stating that it is markedly on the decline. Other observers think this is not the case.

As Medical Officer for Child Welfare in an industrial town, I think it safe to say that there is within the last six years no marked improvement in the number of cases, but a decided improvement in their severity.

For the last few years the Scottish Board of Health/
Health have required from their Medical Officers details as to the number of cases of Rickets in their districts. Before this inquiry, one noticed chiefly the grosser forms of Rickets. Now, at clinics and during the periodic home visits of the Health Visitors, special note is taken of every form, and the numbers accordingly are larger than formerly, mild cases which were missed before being most probably seen and commented upon.

In a Clinic such as mine, among a poor type of people, it is surprising to find how many mild cases of Rickets cure themselves without any intensified form of treatment.

At present I have on my Clinic Register the names of 4,800 children, and of these 202 have suffered, or are at present suffering from Rickets, 86 being mild cases, 85 marked cases and 31 severe cases.

In 1925 I had records of 136 cases.

In their Report for 1925 the Scottish Board of Health give a Table on the prevalence of Rickets among children under five years in some districts, which is as follows:

Table/
Table shewing prevalence of Rickets among children under five years of age in a number of districts.

<table>
<thead>
<tr>
<th>Area</th>
<th>Number Examined</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Total Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasgow</td>
<td>628</td>
<td>49</td>
<td>37</td>
<td>27</td>
<td>18.0</td>
</tr>
<tr>
<td>Edinburgh</td>
<td>350</td>
<td>18</td>
<td>10</td>
<td>23</td>
<td>14.57</td>
</tr>
<tr>
<td>Dundee</td>
<td>250</td>
<td>46</td>
<td>61</td>
<td>22</td>
<td>50.1</td>
</tr>
<tr>
<td>Aberdeen</td>
<td>250</td>
<td>16</td>
<td>3</td>
<td>4</td>
<td>9.2</td>
</tr>
<tr>
<td>Greenock</td>
<td>1,000</td>
<td>60</td>
<td>39</td>
<td>17</td>
<td>11.6</td>
</tr>
<tr>
<td>Paisley</td>
<td>250</td>
<td>All forms, 11</td>
<td></td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>Motherwell (1924)</td>
<td>247</td>
<td>All forms, 135</td>
<td></td>
<td></td>
<td>54.6</td>
</tr>
<tr>
<td>Do. (1925)</td>
<td>278</td>
<td>All forms, 197</td>
<td></td>
<td></td>
<td>70.9</td>
</tr>
<tr>
<td>Stirling</td>
<td>250</td>
<td>15</td>
<td>16</td>
<td>3</td>
<td>13.6</td>
</tr>
<tr>
<td>East Lothian</td>
<td>250</td>
<td>79</td>
<td>13</td>
<td></td>
<td>36.8</td>
</tr>
<tr>
<td>Lanarkshire</td>
<td>99</td>
<td>All forms, 24</td>
<td></td>
<td></td>
<td>24.2</td>
</tr>
</tbody>
</table>

The method of investigation carried out in Greenock was that the records of 1,000 consecutive cases seen at the Child Welfare Clinic during 1925 were examined and reported on by myself as Medical Officer for Child Welfare/
Welfare.

Greenock, being largely a shipbuilding and industrial area, has been seriously affected for four years by trade depression, and most of the children attending the Clinics are subsisting on their parents' Unemployment Insurance, or on the Able-bodied Relief Scale. All extra nourishment given through the Public Health Committee is recommended by me to a special committee, and I therefore see large numbers of children who are inspected fortnightly. In the 1,000 cases recorded specially for the Scottish Board of Health, I have not duplicated any cases, so that the period covered by the survey extended from February till June 1925, and of these 1,000 cases 11.6% were found to suffer from Rickets in a greater or less degree. This is small in comparison with some larger centres, but there a smaller number of children were examined. In Glasgow, where 628 children were examined, 18% were found to be affected, and in Edinburgh, where 300 children were examined, 57% were affected. It is possible in these towns that only sick children were seen.

In Greenock we have a fairly extensive scheme of Health Visiting, and the work is conscientiously carried/
carried out, and I, therefore, do not think many cases escape examination, unless those whose parents are extremely neglectful, and this is as a rule combated.

I am of opinion, however, that the percentage of cases of Rickets found will be higher in 1926 than in 1925, owing to the fact that all the Public Health workers are becoming more adept at noticing slight changes in the children under their care.

I propose in this Thesis to give an account of the modern views of the etiology of Rickets, and to endeavour to correlate these with my own experience.
Historical Outline.

(a) History previous to Vitamin discovery.

There is evidence that Rickets was recognised early in the Christian era. A work "Diseases of Women" by Soranus Ephesius is known. He was a physician in Rome between 98 and 138 A.D. and was also for some time in Alexandria; of the women of the latter town he had a much higher opinion than of those of Rome. He wrote on "How should the child be trained in standing and walking", pointing out that children should not be forced or allowed to walk too soon, owing to the danger of "twisting at the thighs".

In another article he considers "Why the majority of Roman children are distorted". He says some are of opinion that Rome is undermined by cold waters and that the children's bodies are easily chilled, or drunkenness on the part of the parents is considered by others to be the cause. His own views are extremely interesting. "The truth of the matter lies in "inexperience with regard to the rearing of children, "for women in the city have not so great a love for "their children as to have regard to every particular, "as the women of purely Greek stock do". Soranus recommends/
recommends that when a child first begins to sit he should be swathed around with bandages. This is still carried out by the Italian women, and in Greenock it is interesting to find that the result is almost always the development of Rickets. He says "For purposes of making him approach, use a chair on wheels. Thus from a "gradual common growth of all the members, he will "practice walking".

Hippocrates drew attention to a condition which might be Rickets, but which Findlay considers to be more like Spinal Tuberculosis. Homer in his Iliad in 900 B.C. describes a man as "Bandy-legged, lame of "one foot, shoulders rounded, arched down upon his chest!"

There is no history of Rickets in ancient Egypt, but Findlay is of opinion that the Egyptian physicians were not interested in child life.

Lortet of Lyons described a bending of bone, which was found in the remains of captive apes from Theban temples.

Rickets has been known as a disease since the days of Glisson in 1650, and the suggested causes have covered a wide field of speculation. Glisson shewed that there was a distinct difference between Infantile Scurvy and Rickets, which diseases were often confused. He/
He pointed out that pain in Rickets is not so severe as in Scurvy or in Scurvy associated with Rickets, that the Laryngismus Stridulus of Rickets is marked, and he formed the opinion that it might be "produced by the "indiscreet and erroneous regiment of the infant". In the preface to his book De Rachitide, London, 1650, it is shewn that Glisson and Bate were selected to investigate and write a detailed description of the disease "The Rickets". This was believed to have appeared 30 years earlier. Their description is excellent - "Large size of head, wasting of body, thickening of ends of long bones, flaccidity of limbs, deformity of chest, "protuberant abdomen". The post-mortem appearance Glisson notices are apparent increase in size of the liver, gaseous distension of the gastro-intestinal tract. His opinion is "This disease in its own nature is not fatal". He thought it due to unequal growth of the two sides of the bone in consequence of interference with the blood supply.

In 1645 Daniel Whistler published an article on Rickets at Leyden, the title being "De Morbo Puerili Anglorum". Dr. Norman Moore, commenting on this in 1884, says there was nothing new in it, as at that time "Most active Medical Men were discussing the subject".
Moncorvo mentioned that the disease in 1887 was very common in Brazil, and he considered that Congenital Syphilis was the cause. Hansemann in 1906 stated that, though Rickets was uncommon in Japan, young monkeys kept confined developed it.

Bad hygienic conditions embracing Superfoetation, Overcrowding, Want of Air, Sunlight and Exercise are considered by Noel Paton, Findlay and others, to have a marked bearing on the cause of Rickets.

Faulty metabolism and indigestion were given as causes for some time, the probability being that these arise from, rather than give rise to, the disease. Findlay says in his Special Report No. 20, that the majority of Rachitic children have a normal digestion, Diarrhoea and Constipation being the exception. I disagree with this view, as in my experience of children with Rickets admitted to hospital here, it is the exception to find one without Diarrhoea.

Buchholtz in 1904 considered that Ultra-Violet Rays had both a curative and prophylactic effect on the changes in bone. Pritchard in 1923 considered that the cause of Rickets was a relative excess of acid bodies in the system, due to a disproportion between the intake and output of energy.
(b) Vitamin Theory. History of Observations on Rickets as a Deficiency Disease.

In 1888 Lunin published the results of some experiments, and stated that "Other substances indispensable for nutrition must be present in milk besides "Caseinogen, Fat, Lactose and Salts".

Stepp in 1911 and 1912 found that he could keep mice alive for several months upon food such as wheat bread, made with milk, but the mice did not live longer than a month when the diet had been subjected to extraction. If, however, the extract was added to the food, the animals began to thrive again. His conclusion is that it is probable that some unknown substances, indispensable for life, are contained in the solution.

In 1906 Hopkins said that we had had for years knowledge of a diet factor in Scurvy and in Rickets, but that, though we knew how to benefit the conditions, we were still uncertain as to the real errors in the diet. In his experiments in 1912 he found that milk required to be added to an artificial food mixture, carefully purified, containing Caseinogen, Starch, Sugar, Lard and Salts, to enable the animals to grow; without the milk they died, though they could live on the crude mixture/
mixture. Hopkins' results made experimenters realize the importance of what he called "Accessory factors of the Diet".

Osborne and Mendel in 1911, 1912 and 1913, carried out experiments on the factor necessary for growth, and it was found that the growth factor was found in various animal fats, but was absent from oils of vegetable origin. McCollum and Davis 1915 came to the conclusion that two classes of unknown accessory substances were necessary for normal nutrition during growth, one they called Fat-soluble A, the other Water-soluble B. All investigators now admit the need for these two factors. Young rats fed upon diet with both the factors absent die of symptoms of the want of Water-soluble B, often not having had time to shew symptoms of the want of Fat-soluble A, enough of the latter being probably stored in the body to prevent the symptoms developing until the stores are reduced. A large amount of work has been done with the Vitamins A and B in connection with Rickets by Mellanby 1918, McCollum and Davis 1913 and Korenchevsky in 1922, their work being considered later.

In 1890 Palm drew attention to the relation of the geographical distribution of Rickets with the presence/
presence or absence of sunlight. Huldschinsky in 1919 and 1920 shewed that Rickets could be cured by exposure of the patient to the Ultra-Violet Rays of the Mercury Vapour Lamp, and in 1921 Hess and Unger shewed similar results with sunlight. They also shewed that sunlight, after passing through glass, lost its anti-rachitic property. In experiments carried out in Vienna in 1919 to 1922 Chick, Hume and their colleagues shewed the beneficial effect of sunlight on the cure and prevention of Rickets in children, even where the Vitamin A content of the food was low.
As recognized by the older clinicians, Rickets is a disease seen mainly among children of six months old and over, and among the poorer population.

Experiments carried out by Chick, Hume and Mackay in Vienna in 1919 - 1922 shewed that there Rickets could generally be diagnosed by X-ray during the first six months of life, and "that the first six months of life proved to be a period of special susceptibility to the disease".

It is more commonly seen in industrial areas, and most observers consider it uncommon in tropical countries, though Still states that it is prevalent in Australia, South Africa and South America.

Findlay in a report to the Medical Research Council estimates that it affects 50% of children in industrial areas, while in the Report of the Scottish Board of Health 1925, the percentage given in 1924 of the children examined at the Child Welfare Clinics was 54.6, and in 1925 70.9, but here again more careful diagnosis may be being made.

Some observers consider the possibility of an inherited tendency to Rickets. This is difficult to prove/
prove, as in cases where it is considered possible, there is usually the hygienic factor to be taken into account. Pfeiffer shewed that, where the elder children were rickety, the younger members of the family also shewed the disease, and he found that in these cases the mother might also shew symptoms of the disease. Kassowitz regards Rickets as a Congenital disease, not necessarily inherited, but explained by a hereditary predisposition.

Paton, Findlay and Ferguson, in investigations in Glasgow, came to the conclusion that the mothers of non-rachitic children were found to be in better health than those of rachitic children.

Korenchevsky mentions a case observed by Drs. Dalzell and Mackay in 1920, when the child of a mother suffering from Osteomalacia, though suckled by a healthy woman, developed severe Rickets at 4½ months old, whereas the child of the healthy woman remained normal. In my records I have only one case which would appear to bear out the question of heredity. The parents were both badly deformed as the results of Rickets. The child was born by Caesarean Section, and got every care. At nine months she shewed slight evidence of Rickets in the chest. These improved and her general condition/
condition remained good until she was three years old, when, after a slight attack of illness, she developed marked knock-knee on the left side. She was admitted to hospital, and much improved by treatment with Ultra-Violet Rays.

Paton and Findlay in their researches have pointed out that Rickets is common in dogs, and unknown in cats, and that some breeds of dogs appear more predisposed to it than others.

Owing to the effect of the disease on bones, there is a tendency to consider it in this light only, but it must be remembered that ligaments, muscles, the alimentary tract and the nervous system can all be attacked by it, and that the results in these cases are quite as serious as those in the bony system. The main danger of Rickets is the lessened resistance to other diseases in the children affected by it. I have seen this markedly in a hospital of 20 beds for children from birth to five years of age, of which I am in charge, and where a large proportion of the cases have Rickets in one form or another. Mild Influenza, Tonsillitis, Measles and Whooping Cough sweep through the wards at an alarming rate, and often nullify months of treatment.

By some it has been considered that Rickets is due/
due to a Bacterial Infection of the blood, causing normal ossification to be interfered with. Morpurgo isolated diplococci from the marrow, liver, kidneys and spleen of rats affected by Rickets. These he injected sub-cutaneously and produced Rickets or Osteomalacia in more than half of the rats experimented on. Korenchevsky considers that Morpurgo's experiments are nullified by his inattention to the feeding of the animals.

Koch injected streptococci intravenously into puppies, producing general infection of the system, after which some of the puppies developed changes similar to Rickets in the skeleton. It is a question as to whether the Rickets may not have predisposed the animal to absorbing extraneous infection.

There may be a possibility that Hypo-thyroidism causes Rickets. It was suggested that the anti-rachitic action of meat might be due to the increase of metabolism effected by it. Mellanby thought that if this were the explanation, anything which would increase metabolism would act in the same way. He, therefore, did experiments to see the effect of Thyroid on the development of Rickets, and found that, though metabolism was increased, there was not any great anti-rachitic result.

O.Leyton/
O.Leyton 1926 points out a similarity between Goitre and Rickets, in the fact that the individual has in each a deficiency in the supply of Iodine and Iodine Salts. The Para-thyroid glands are considered to have a control over Calcium metabolism. Removal of the Para-thyroids in dogs leads to an increase in the amount of a substance guanidin in the blood, and excess of guanidin in rabbits and guinea pigs leads to a decrease of Calcium in the blood.

The "Domestication" theory has for some time been considered largely in the search for the cause of Rickets, and to those of us working in industrial areas, it still looms before us as a markedly contributory cause in the production of the disease. This theory embraces Overcrowding, Tenement Buildings, Want of fresh air, Bad Hygienic conditions and Poverty.

The theory that Rickets is due to an insufficient Calcium intake has various followers, but Mellanby points out that experimental work shews that this alone will not produce Rickets. Miwa and Stoeltzner fed puppies on horse flesh and distilled water; the rickety changes in the bones were small, but there was Osteoporosis in the shafts of the bones.

Mellanby's experiments shewed that abundance of/
of Calcium does not prevent Rickets, a puppy being given a Rickets producing diet with Calcium phosphate. Severe Rickets developed. Lack of Lime Salts in the food may produce Rickets when tried experimentally on animals.

All infants' foods, however, contain Calcium to a greater or less degree, and the deficiency in the system may be due to the fact that the type of Calcium given cannot be assimilated.

Excessive Carbohydrate in the food is considered to be a cause of Rickets, due to the production of an excess of Lactic Acid which dissolves the Calcium being laid down in the bones.

Harriette Chick in detailed experiments in Vienna found that Rickets developed in infants receiving a diet of milk with much Carbohydrate, while infants receiving more milk with very little sugar and the addition of cod-liver oil did not develop the disease.

The Vitamin theory was suggested in 1918 by Mellanby, who thought that Rickets might be produced by the absence in the diet of a special food factor, which, in 1921, he came to the conclusion was identical with Vitamin A. This was first found in butter and egg-yolk, but/
but the greatest source is Cod-liver oil.

Vitamin D or the anti-rachitic Vitamin has also a marked bearing on the cause of Rickets. Hume shewed that under treatment by Ultra-Violet light with a poor supply of Vitamin A rats did not develop Rickets. Her experiments, which come to the same conclusion as those of Goldblatt and Soames, seem to shew that, either small amounts of Vitamin A are also necessary when the animal is under irradiation by the Ultra-Violet Rays, or that the Vitamin stored in the body is gradually yielded up in sufficient quantity to produce normal growth until the supplies are exhausted.
Discussion of the Various Theories Seriation.

(a) Vitamins and their relation to Rickets.

For some years the question of Rickets being caused by want of, or deficiency in, substances known as Vitamins has occupied the attention of many investigators. Those substances are now considered as established articles of diet, but we do not know their chemical nature.

We are aware of the Fat-soluble A, the Water-soluble B, the Water-soluble and Anti-scorbutic Vitamin C, and the Anti-rachitic Vitamin D.

Hutchison states that Fat-soluble A has two component parts, the growth promoting and the anti-rachitic, and that vegetable fats belong to the first category, while animal fats belong to the second. Findlay considers that Vitamin B is essential for the formation of Nucleic acid in the body, and growth or muscular activity uses it up rapidly. Investigations as to Beri-beri by Fraser and others in the Malay States shewed that Beri-beri was caused by eating polished rice, which was poor in Vitamin B, and that it could be prevented by eating the rice unpolished, or by feeding the infants of Beri-beri mothers on extracts of rice polishings.
polishings. Mellanby, in his Report on Experimental Rickets 1921, points out that, though Vitamin A is of the first importance in the etiology of Rickets, it must be remembered that it works in close connection with the rest of the diet.

The Fat-soluble Vitamin is specially concerned with the Calcification of bone, but Mellanby shews that, though the prime factor, the others, Calcium and Phosphorus in the diet, Protein and Exercise are all necessary.

In Mellanby's experiments, 1919 - 1921, all carried out on puppies, he shews that, for some weeks, puppies can live and thrive on a diet poor in Fat-soluble A, but after these few weeks Rickets develops fairly rapidly, and the animal becomes progressively more ill. The first change is seen in the lower end of the Ulna, which rapidly loses its clean-cut edge and X-ray examination shews it has become rounded and blurred. Mellanby made experiments with different fats, working with linseed oil, butter, olive oil and cod-liver oil, the results of which will be seen from the/
the following Table:-

<table>
<thead>
<tr>
<th>Fat.</th>
<th>17 weeks</th>
<th>Rickets</th>
<th>Dried Bone. Ca.O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linseed Oil</td>
<td>&quot;</td>
<td>+</td>
<td>21.6 %</td>
</tr>
<tr>
<td>Butter</td>
<td>&quot;</td>
<td>-</td>
<td>26.9 %</td>
</tr>
<tr>
<td>Olive Oil</td>
<td>&quot;</td>
<td>+-</td>
<td>23.79 %</td>
</tr>
<tr>
<td>Cod-liver Oil</td>
<td>&quot;</td>
<td>-</td>
<td>27.78 %</td>
</tr>
</tbody>
</table>

Further, his experiments shewed that, with animal fats, puppies fed on butter had hard periosteal bone, but the epiphyseal growths were not exactly normal, and that puppies fed on lard had normal epiphyseal growth and soft bones.

The addition of meat to the diet improved the epiphyseal ends of the bones, but had no effect on the periosteal bone. Osborne and Mendel shewed that Fat-soluble A in butter and cod-liver oil is very heat-resistant. It was found by Mellanby that the addition of Lean Meat to the diet prevented the development of Rickets, the cause for this not being clearly ascertained, the theories being that the meat may contain some Vitamin A, or that it may aid in metabolism by increasing the appetite of the animal, or by encouraging digestion and absorption in the alimentary canal. It assists/
Increase in the diet of bread and carbohydrates increases the tendency towards Rickets, especially in animals receiving little exercise.

Again Mellanby found that, while feeding on pure milk was successful in preventing growth of Rickets, if the constituents of milk were altered, the action was also changed. Casein, normally alkaline, when added to the diet, did not produce Rickets, whereas Caseinogen, acid in reaction, did so. In five experiments, Mellanby shewed that dogs fed on oxidised butter plus extracted casein developed bad Rickets, and those on normal butter remained healthy.

The diet of the puppies was Separated Milk 175 c.c., Bread 100 grm. or more, Orange Juice 5 - 7.5 c.c., Lean Meat 5 grm., Salt 1 grm.

<table>
<thead>
<tr>
<th>Above Diet.</th>
<th>Ca.O</th>
</tr>
</thead>
<tbody>
<tr>
<td>321. 8 wks.</td>
<td>5 - 10 grm. Oxidised Butter. Rickets. 5.9%</td>
</tr>
<tr>
<td>325. &quot;</td>
<td>5 - 10 grm. Fresh Butter. No Rickets.</td>
</tr>
</tbody>
</table>
1. Butter with its Fat-soluble A destroyed allowed Rickets to develop more rapidly.

2. Casein with or without its Fat-soluble quota, allowed Rickets to form when fresh butter was eaten. See 323.

3. Extracted or Unextracted Casein are both bad.

It is considered possible by some observers that the acid of the Caseinogen may act upon the calcium of the body and prevent it from being absorbed. Göttting has found that oxalic acid added to the food of puppies causes osteoporosis, but Mellanby argues that, if this were the case, dogs receiving lemon juice in their diets would develop Rickets, and this did not occur with him.

An interesting point was noted by Mellanby, e.g., that Rickets did occur at times in butter-fed animals, and that butter made from Summer milk was more anti-rachitic than that made from Winter milk. This fact is taken advantage of nowadays in exposing milk and other food stuffs to Ultra-Violet Rays, and by some Dairy-keepers in giving the cows a daily exposure to the rays, as there appears to be some evidence that Vitamin A and Vitamin D act better in the presence of sublight. Goldblatt and Soames 1923 say there is no definite evi­dence/
idence that the Ultra-Violet Rays are dependent on the presence of the anti-rachitic Vitamin for the cure of Rickets, but the Medical Research Council in their Report in 1924 think it is possible.

Dr. Chick and her colleagues carried out a long investigation on the cause of Rickets, working with infants in a clinic in Vienna in 1919 - 1922.

All the infants lived under the same excellent conditions of hygiene, which did not prevent the development of Rickets. It was found that the first six months was the period of greatest susceptibility to the disease. Dr. Chick considered that the season of the year had a distinct bearing on the production of Rickets, all cases developing during the Winter months and tending to cure during the Summer months, when they could be out of doors. Two diets were used, Diet I. containing milk with much carbohydrate, Diet II. consisting of milk with cod-liver oil. Diet II. cured Rickets indoors in Winter. Diet I. seemed to be sufficient when the child was treated in sunlight during the Summer.

Diet I., which normally produced Rickets, did not do so when the child was treated with exposures to the Ultra-Violet Rays. The conclusion arrived at from Dr./
Dr. Chick's investigations would seem to be that Vitamin A and Vitamin D are closely related in the prevention and cure of Rickets.

(b) Calcium salts and their relation to Rickets.

The diet must contain a sufficiency of Calcium. Dr. Bengt. Hamilton has calculated that the amount required for metabolism in the infant is .2 grams in 24 hours, and that if this is not supplied, the amount has to be taken from the bones. Many workers consider that Rickets is due to a deficient Calcium intake. Experimental work has shewn that, while deficient intake of Calcium will exaggerate the type or hasten the onset of Rickets, Calcium deficiency alone will not produce it.

Stoeltzner fed puppies on horse flesh and distilled water, and found that the endochondral changes were small but that there was osteoporosis in the shaft of the bone.

Götzting also produced osteoporosis in a similar manner.

Dibbelt produced Rickets plus osteoporosis when/
when there was anti-rachitic Vitamin and no fat in the diet, and osteoporosis only when fat and its Vitamin content were eaten.

The addition of Calcium to the diet will not prevent Rickets. There is evidence of an inter-relation between the anti-rachitic Vitamin, Calcium and Phosphorus, and it is by the proper balance of those substances that bone calcification is regulated.

Korenchevsky points out that the Calcium requirement of the puppies used in Mellanby's experiments would only have been covered if the puppies had retained 70% of the Calcium supplied, which is not likely.

McCollum and other workers in experiments on rats found that the anti-rachitic action of butter can only compare with that of Cod-liver oil when the Calcium is relatively high. Want of Calcium causes an increase in the water content of the skeleton, and decrease in its Calcium content.

Mellanby thought that Acid-Caseinogen, which contains no Calcium but much Phosphorus, is more Rickets-producing than Casein containing Calcium and Phosphorus.

In experiments on pigs by Elliot and others, it would appear that the Calcium and Phosphorus balance was/
American investigators considered the question of Phosphorus as most important; they maintained that starvation cured Rickets by mobilizing Phosphorus, and that this was also the action of Ultra-Violet Rays.

(c) Overcrowding and Industrial Conditions in relation to Rickets.

These as causes of Rickets have been considered by many observers to be of paramount importance, and among those who strongly emphasize them are the "Glasgow" school, Noel Paton, Findlay and others. In industrial towns, the buildings are usually of the tenement type, the rooms are overcrowded, there is no ground for the children to play on with safety, and careful mothers keep their children indoors unless they are able to take them out. Again, in other cases, as often happens in Greenock, the mothers are seldom to be found in their own homes by the Health Visitors, they are always "out", which resolves itself into the fact that they are visiting with their children in one of the other rooms in the building, and that the children sel-
dom get any fresh air.

Hansemann found that wild animals confined in Zoological Gardens are apt to develop Rickets. Findlay found that puppies fed on porridge and milk and confined to rooms in the laboratory developed Rickets, while those fed similarly, and allowed exercise in the open air, did not. Mellanby does not agree with this theory, and considers that it is because the diet was poor in essential substances that the results were bad.

Findlay and Watson again made some experiments, giving a better diet, and still believe that want of exercise is the main feature.

Paton now agrees with the experiments of Bull that with the confinement theory there is also an infective agent to be considered.

Mellanby has done three experiments, and finds that (1) Puppies on a good diet, confined to kennel, have not developed Rickets. (2) Diet has been poor in Vitamin A and the puppies have been allowed freedom - Rickets has developed. (3) Puppies were made Rickety and then confined to their kennels; better food was given them and the Rickets began to improve in spite of the confinement.

Findlay and Ferguson made in 1918 an inquiry into/
into diets and home conditions of rachitic and non-rachitic families in Glasgow. Their conclusion was that there was little difference in the diet, but much difference in their hygienic conditions. It is nowadays considered that want of fresh air is not so important as want of sunlight, but that, even with much sunlight, the diet must be adequate, as sunshine alone does not prevent Rickets.

It would appear from the above that Rickets should be unknown in country districts, but this is not the case, though the numbers are fewer, and the cases tend to cure themselves rapidly. Observations in India by Hutchison support the confinement hypothesis of Findlay, Rickets being commoner among the higher castes than among those of lower caste.

In Dundee in 1925 it was found that, among 80 children from one-roomed houses, 150 from two-roomed houses and 20 from three or more roomed houses, the percentage of children with Rickets was 50% in all.

Of the 1,000 children whom I examined in Greenock for the Scottish Board of Health in 1925, and who were taken as they presented themselves at the Child Welfare Clinic, 116 were found to have Rickets - 60 being slight, 39 being medium and 17 severe - the parents/
parents of 82 of the cases were unemployed and subsisting on the Unemployment Benefit or on Parish Relief, and most had been unemployed for three years or longer.

Of the 116 cases, 55 occurred in houses of one apartment, tenement in type, and 46 in houses of two apartments, tenement in type. In Greenock, however, for the last few years, a two apartment house generally contains two families, so that the fact of a house being larger is no criterion for better ventilation.

Number of Pregnancy.

Of the 116 cases, 12 were 1st pregnancies,
17 were 2nd "
22 were 3rd "
20 were 4th "
13 were 5th "
8 were 6th "
9 were 7th "
6 were 8th "
3 were 9th "
3 were 11th "
3 were 12th "

this bearing out the usual theory in industrial towns that a mother can manage to get her first or even second child out, but that three or four young ones are too many/
many to dress and get out, and they therefore stay indoors more. After this, however, the elder children begin to go out and play by themselves, often taking the younger ones with them, and the latter get more fresh air than their elder brothers and sisters, and do not so often develop Rickets. This supports the "fresh air" School of thought, as there is probably less food for the younger children as the family increases, the rates of wages being stationary.

With regard to the age of the mother, I found that the larger proportion occurred when the mother was 25 - 30 years of age, but this again comes round to industrial conditions and age of marriage.

The following Tables give a list of the ages of the 1,000 cases examined by me, and of the feeding:

<table>
<thead>
<tr>
<th>Not affected by Rickets</th>
<th>Affected by Rickets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 2 months, 111</td>
<td>-</td>
</tr>
<tr>
<td>2 3 months, 62</td>
<td>-</td>
</tr>
<tr>
<td>3 4 months, 45</td>
<td>-</td>
</tr>
<tr>
<td>4 5 months, 48</td>
<td>-</td>
</tr>
<tr>
<td>5 6 months, 47</td>
<td>-</td>
</tr>
<tr>
<td>6 7 months, 35</td>
<td>3</td>
</tr>
<tr>
<td>7 8 months, 37</td>
<td>1</td>
</tr>
<tr>
<td>8 9 months, 31</td>
<td>4</td>
</tr>
<tr>
<td>9 10 months, 29</td>
<td>6</td>
</tr>
<tr>
<td>10 11 months, 17</td>
<td>1</td>
</tr>
<tr>
<td>11 12 months, 92</td>
<td>19</td>
</tr>
<tr>
<td>1 2 years, 164</td>
<td>64</td>
</tr>
<tr>
<td>2 3 years, 95</td>
<td>11</td>
</tr>
<tr>
<td>3 4 years, 55</td>
<td>7</td>
</tr>
<tr>
<td>4 5 years, 16</td>
<td></td>
</tr>
<tr>
<td>Total, 884</td>
<td>116</td>
</tr>
</tbody>
</table>

Feeding/
Feeding.

Breast fed till 1 year, 54
Breast fed till 9 months, 9
Breast fed over 1 year, 11
Breast fed over 2 years, 1

Breast fed under 1 year, 17

1 till 3 weeks, then Patent Barley.
1 till 6 weeks, then Oatflour.
1 till 7 weeks, then Semolina.
1 till 2 months, then milk, followed by dried milk, and milk again.
1 till 3 months, then dried milk, followed by Sister Laura's Food.
1 till 4 months, then milk.
3 till 5 months, one then having ordinary food, 1 milk and 1 oatflour.
4 till 6 months, one then having milk and oatflour, 1 dried milk, 1 milk and 1 bread and milk.
2 till 7 months, one then gruel and one ordinary food.
2 till 8 months, one then ordinary food and one arrowroot.

Breast and Bottle from Birth, 3, one having Dried milk and 2 Sister Laura's Food.

Artificially/
Artificially fed from Birth, 21.

Cow's milk, 9
Sister Laura's Food, 5
Milk and Virol, 1
Savory and Moore's Food, 1
Oatflour, 1
Milk and Barley Water, 2
No earlier record of feeding, 1
Anything from birth, 1

Total, 21

(d) Acidosis Theory of the Cause of Rickets.

Hamilton and Tobler assert that the chief function of Calcium in internal metabolism is to neutralize acids, and that no Calcium can be spared to make bone until the necessary amount has been given for neutralization purposes. Therefore a normal intake of Calcium may be insufficient for dealing with a system where there is excess of acid formation. In 1923 Eric Pritchard put forward a statement that he was convinced that he could find in all cases of Rickets definite reasons for explaining a disturbance in the normal/
normal relationship of acid and Calcium in the system. All food should theoretically leave the body only as waste products, e.g., Carbonic acid, urea and water. Practically this does not occur, and there is always some remainder. Pritchard holds that a healthy body with a correspondingly healthy output of energy can use up much more food without excessive acid production than can a weaker body which absorbs correspondingly little and gives out less energy. The proof of excessive acid bodies is excess of ammonium in the urine, and this has been shewn by Amy Hodgson. Pritchard holds that Alkaline treatment of Rickets by neutralizing acid products ought to be the best, but it must be continued over long periods. Calcium is not excreted by the kidneys, but by the bowel, and in the faeces Calcium Soaps are found in excess in Rickety conditions.

Pritchard considers that his views as to excessive acid production or deficient neutralization are well founded, as one finds practically that every case of Rickets must be treated on its own merits, but he thinks that, with all other treatment, the loss of Calcium must be combated by an adequate supply of Calcium Salts.

Summary/
Summary.

The Vitamin Theory.

This has the greatest following as a factor in the production of Rickets. More experiments have been done and more matter published in connection with it than with any of the other theories. As M.O.i/c Child Welfare in an industrial town, I find that the proof of theory is difficult in practice. One cannot try experiments with children. If a child in hospital does not shew rapid signs of improvement, it is promptly removed by its relatives, and one naturally does not wish it to go home in poorer condition than on admission. There is no doubt that in such a town as Greenock, in severe financial depression such as has occurred during the last five years, the feeding of expectant mothers is not what it should be, and if the theory that Calcium is stored up in the foetus chiefly in the last two months of pregnancy is correct, it is obvious that the mother requires special care at these times.

I have found that Cod-liver oil and Cod-liver oil Emulsion are of great benefit in helping to cure cases of Rickets, and in Hospital the Ultra-Violet Rays have been of inestimable help.

The/
The feeding of the child is bad in industrial towns in Scotland. Having worked for some years in an industrial town in England, though one without tenement buildings, I seldom saw a case of Rickets, but the feeding there was distinctly better than it is here. I never entered a house at the dinner-hour where there was not a dinner cooked consisting generally of potatoes, vegetables and gravy from the meat which the father had. In Greenock I fear that the usual dinner among the labouring class is tea, and some bread and jam or sliced sausage. In hospital, it is exceedingly difficult to get the children to take their soup, or meat and vegetables, and milk pudding has generally to be given as a first course, otherwise it would not be taken at all.

With regard to the theory that deficiency of Calcium Salts causes Rickets, it would appear sound, if it were not for Korenchevsky's experiments shewing that the intake in many cases would require to be much larger than the body could deal with, and that therefore the Calcium would simply be unassimilated.

The Domestication theory appeals very much to those of us who work in the West of Scotland. The overcrowding, the attic rooms with one small window in a/
a corner, or the basement apartments with gas continually lit, the craze for making a little extra money by letting out any available space, all militate against the child having the necessary fresh air. The ubiquitous grandmother or neighbour who gives much bad advice to the mother is also a thorn in the flesh of the Public Health Worker, who is honestly doing her best for those on her district.

It is a fact that we have many more cases of Rickets in children from the low lying parts of the town, where it is dangerous for them to play on the street, than in the higher parts, where the houses are not of a much better type, but where the streets are so steep there is little traffic, and the children get moving about freely. The type of parents is the same and the feeding certainly no better.

The delay in housing schemes for slum areas has opened the way to all sorts of abuses, and it is no uncommon thing to find a man appealing for the benefit of rent restriction on the ground that the house is causing ill-health to his children, and at the same time absolutely refusing to allow his children to be taken out in case they get a cold, with the result that three or four children under five years of age in one/
One family, and not walking, can be found in one district.

Eric Pritchard's Acidosis theory seems ingenious and would be the explanation of many things that puzzle us, including the fact that one can make rules of no kind for the treatment of Rickets, and that each case must be treated as one finds best at the time.
Treatment.

Just as the causes of Rickets have been widely conceived and have now been gradually reduced to want of Vitamins or to Acidosis, so treatment has been narrowed from the wider limits to the necessity of a full supply of Vitamins.

As Rickets was considered to be due to want of enough Calcium to build up new bone, at one time lime water was largely given to infants, so that the deficiency might thereby be made up. Nowadays it is found that this may defeat the purpose for which it was intended, and may interfere with the metabolism of the fat which is more important to the child. Still says that in some parts of Europe Phosphorus is much used in the treatment of Rickets, doses of \( \frac{1}{100} \) grain being given thrice daily.

It must be our first attempt to see that mothers are as healthy as possible during their time of pregnancy, and that food and exercise are taken in suitable amounts, and to this end Ante-natal Clinics are of increasing importance. The work of preventive medicine/
medicine is but in its early stages, and much prejudice is to be removed, prejudice of the well-to-do who appear to grudge advice and help being given to their poorer neighbours, prejudice of those doctors who do not trouble to give this advice and who scoff at those who do, prejudice of midwives who wish to make their patients think they are omniscient, prejudice of the mothers and grandmothers of the patients, and of the patients themselves. Those, in my experience of nearly seven years as M.O.i/c Child Welfare, are quickly being overcome, the most cheering part of the work being the way in which midwives send their patients to the Ante-natal Clinic for advice, and the fact that the mothers of the patients often accompany them and ask pertinent questions. In a town such as Greenock, however, where work has been almost at a stand-still for five years, the expectant mother cannot be well fed. The rents charged for the poor apartments in which they live are high, and where the unemployment allowance for a husband, wife and one child is 23/6d. per week, with a probable rent of 10/- per week, very little remains for food. We try to combat this in the last two months of pregnancy by giving such patients one pint of milk per day, and in some cases/
cases oatmeal is also given. Soup Kitchens have been started, but these are not taken advantage of sufficiently. As I have already pointed out, tea, bread and margarine are more appreciated in many homes than is good soup.

Of the 116 cases in my record, the parents were on Unemployment Pay or Parish Relief in 81 cases.

**Feeding of the Child.**

It is undoubtedly the fact that children should be breast fed until they are nine months old. In Greenock the time is generally one year, though other food may also be given for a few months. Until 20 years or so ago, where the mother could not do this, a wet nurse was employed, but this course is seldom adopted nowadays.

In my series of cases, nine were breast fed till nine months or ten months, and Rickets were found at eight months and upwards, but in five of these cases the mothers' statements are unsatisfactory, and it is more than likely that the feeding was mixed. In Greenock one views with alarm the hold that bottle feeding is gaining over the mothers, fostered often by their own medical men, who, on very scanty evidence, consider/
consider that either the mother or the child is suffering from the effects of breast feeding. The other side of the picture is that in which the mother will not stop breast feeding the child, ten in my series being breast fed from 1 1/2 years up to 2 years. These tactful Health Visiting can do much towards remedying, and particularly is this so in the case of Health Visitors of long standing, who know the parents and have visited several members of the family.

Of those mothers who do not breast feed their children for nine months the ideas as to proper feeding are varying. Again referring to my 116 cases, three children under nine months had assisted feeds, two of Sister Laura’s food (which is a dried cereal much used in the West of Scotland, and which certainly does very well in some cases of digestive disorders, without, in my opinion, tending particularly to the production of Rickets), and one of Dried Milk. Of those under nine months also, Patent Barley was given in one case after three weeks of breast feeding. Cow’s milk was given in three cases after four, five and six months breast feeding respectively.

Semolina was given in one case after seven weeks breast feeding, Oatmeal Gruel in one case after seven/
seven months, Glaxo in three cases after two, three and six months respectively.

Sister Laura's food was given in one case after three months, Bread and Milk in one case after six months, Oatflour in two cases after six weeks and six months respectively.

Ordinary food was given in one case after five months, and this case of Rickets was a mild one. It was also given in one case after seven months, and in one case after eight months, while Arrowroot was given in one case after eight months. Children who were artificially fed from birth were, nine on Cow's milk, five on Sister Laura's food, one on Savory and Moore's food, one on Oatflour made with milk, two on Milk and Barley Water and one on Milk and Virol. From this it would appear that there is some uncertainty as to which patent or artificial food is most productive of Rickets, and I am of opinion that the reason why Cow's milk is an unsatisfactory diet here is that the milk is given in too diluted a state. To help as much as possible in giving children milk, milk is given from the Child Welfare Clinic to any necessitous case up to one year of age, and to any necessitous case over one year which is underweight, rachitic, or suffering from other disease. Again/
Again, much labour is expended, generally unsuccessfully, in trying to prevent mothers from fastening their children in shawls. This does not affect the child badly until six months old, but after that, the shawl has a distinctly bad effect on children who should be kicking out more than the tight folds of the shawl permit. This is largely due to the fact that the mother is in a hurry and cannot wait for a toddler to make its way by her side, and no amount of advice appears to stop the habit.

Medical measures are limited almost entirely to Emulsions with Cod-liver Oil either with or without Chemical Food. The mothers themselves do not care for the smell of Cod-liver Oil, and will not give it to their children, assuring me that the child will not take it, but they say their children take the two combined readily.

I advise all mothers of Rickety children to give them salt baths and to see that the feet, legs and spine are well rubbed daily. Fresh air is insisted upon as much as possible, here again the Health Visitors doing useful, but often thankless work.

Ultra-Violet Ray Treatment.

This I have not been able to use in connection with the aforementioned cases. I am, however, in charge of/
of a small hospital of 20 beds for children up to five years of age, and in November, 1925, a K.B.B. Lamp was installed, and the records for treatment are as follows:-

**RICKETS.**

_Slight_ - 11 cases aged 9 months to 3 years 2 months. 4 have had under 6 treatments, but all have improved slightly. 7 had treatments from 13 - 33 in number, and ranging from 4 - 12 minutes, and all 7 were much improved.

_Fairly Severe_ - 11 cases aged 1 year 8 months to 4 years. 2 had only 3 treatments before dismissal. 9 had treatments from 9 - 46 in number. One died of intercurrent disease, and the other 8 were much improved.

_Severe_ - 15 cases aged 1 year 1 month to 4½ years. 2 of these died - 1 of acute Rickets and 1 of Influenza - and 1 had to be dismissed after Influenza because of lack of beds. These had 4 - 8 treatments. 12 had treatments varying from 15 - 122 in number, 9 results being excellent and 3 very good.

**PNEUMONIA with RICKETS.**

2 cases aged 1 year 8 months to 2 years. 1 was only tested, his condition not warranting treatment, and died, and the other had 2 treatments of 4 minutes, took intercurrent disease and was transferred to Gateside Hospital.
1 had 10 treatments of 4 minutes each, but was unimproved. 1 had 38 treatments of 4 - 10 minutes and was much improved. 1 had 5 treatments but died.

**TUBERCULAR SPINE with RICKETS.**

1 case aged 8 months had 43 treatments of 4 - 10 minutes each. Gained weight and was much improved.

**TUBERCULAR ABDOMEN with RICKETS.**

3 cases aged 11 months to 3½ years. 1 was taken home after 1 treatment, 1 had 20 treatments of 4 - 10 minutes and was unimproved. 1 had 45 treatments of 4 - 20 minutes with loss of weight but general improvement.

**ALIMENTARY DISEASES with RICKETS.**

11 cases aged 10 months to nearly 3 years. 3 had under 6 treatments, 2 of whom are improved, 8 had 24 - 75 treatments of from 4 - 16 minutes. Of these, all were much improved.

**SKIN CONDITION with RICKETS.**

1 case nearly 4 years of age had 47 treatments of 4 - 16 minutes, the result being very good.

**CARDIAC**/
CARDIAC CONDITION with RICKETS.

1 case nearly 5 years of age had 5 treatments of 4 - 6 minutes with gain in weight and improvement.

RESPIRATORY CONDITION with RICKETS.

9 cases aged 7 months to 4 years. 6 had under 6 treatments, but all improved except 2, one of whom has taken intercurrent disease, the other having lost weight with his respiratory condition. 3 cases had from 8 - 84 treatments of 4 - 10 minutes, and all improved.

DEBILITY AFTER DIPHTHERIA with SPINAL RICKETS.

1 case aged 1 year and 2 months had 18 treatments of 4 - 12 minutes and was much improved.

DEBILITY AFTER INFLUENZA with RICKETS.

1 case aged 4½ years had 5 treatments of 4 - 6 minutes, gained weight and did well.

From this there is not the slightest doubt that the Ultra-Violet Rays are of the greatest benefit in the treatment of Rickets. The treatment is given four days a week, and the patients, after being tested, are given 4 minutes treatment, rising to 20 minutes. I find that it is a good plan to give the 4 minutes treatment for one week, then 5 minutes and so on. After the patient has had the full range up to 20 minutes per day/
day I find it best to cut off the treatment for at least a fortnight, and to begin again at 2 minutes. The patients, after they have reached the 20 minute period, are apt to keep stationary in weight, whereas, after the rest, they begin to put on weight again. The cases of fairly acute Rickets benefit at once, as there appears to be less pain in the bones after a few treatments.

I have not found that the Ultra-Violet Rays have increased the appetite much, and the Rachitic children are still difficult to feed.

As well as the Ultra-Violet Rays, the children in Hospital are all massaged daily, and exercised. I consider that the weakness of the muscles and ligaments is better combated by exercise than by rest. One naturally rests the acute cases, but once this stage is over, exercise is essential, as most of the bad results of Rickets in Greenock are due to the fact that the parents will not take the trouble to see that their children are exercised. Graduated amounts of exercise are given, each case being treated on its merits, and toys of the wooden pushable varieties are used in this.

Hot salt baths are given for treatment and cold douches to the spine in certain cases, but those are not given where there is any nervous effect on the/
The food of the Rachitic children is varied, but dinner consists of Soup made with vegetables, or of mince cooked with vegetables, and of pudding. It is very difficult to get some of the patients to take this food, and for weeks at a time it may be necessary to spoon-feed.

With regard to medicine, Cod-liver Oil is now given to all cases in 15 - 30 minim doses thrice daily, and is liked by all the patients. I have used Emulsion of Cod-liver Oil alone, or with Chemical Food, Virol, Citrate of Iron and Quinine, Bone marrow extract, and Thyroid extract. The last I have not found particularly satisfactory, owing to the difficulty in finding the suitable dosage, the Rachitic children reacting to it with high temperatures or with Diarrhoea.
Summary and Conclusions.

The theories as to the Cause of Rickets which have most vogue are:

The Vitamin Theory,
The Domestication Theory, and
Eric Pritchard's Acidosis Theory,
all of which one can follow in one's work as probable causes.

The results of Rickets are still painfully obvious, but there is no doubt that Child Welfare work is now bearing fruit, as we get the early cases to deal with. There is, however, a great handicap in the ignorance and often criminal negligence of the parents. Action can be taken against parents only for obvious cruelty, shewing itself in dirt or bruises. Until the law is tightened in this respect, and while a child is not considered ill-treated who is kept in a dark, damp basement, and who seldom gets any exercise, much still remains to be done.

The striking facts with regard to treatment are the excellent results with Cod-liver oil, and with exposure to the Ultra-Violet Rays. In 1924 we had a hot Summer, and our patients were out all day in the sunshine/
sunshine, but our results with Rickets were not nearly so rapid as they have been since the installation of the Ultra-Violet Rays Lamp. My opinion, however, is that the massage, baths and general treatment must be continued with the Rays.
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