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Appendicitis, Rainfall and Bowel Complaints.

By

CAPT. S. K. RAY, M.B.

INTRODUCTION.

The present investigation has been undertaken with a view to finding out some definite cause of appendicitis which accounts for a large number of cases in India. The statistical material has been kindly worked out by Mr. P. C. Mahalanobis, late Superintendent of Alipore Observatory, Calcutta and forms the second part of this paper. My materials for appendicitis have been taken from the Medical College Hospital, Calcutta. The clinical observations were made on 183 cases of appendicitis which include 43 cases operated on by myself and for charts and statistical purpose records of 327 cases were collected. These represent the admissions of cases of appendicitis in the Hospital during the years 1918 to 1922. All sorts of appendicular troubles, viz., the chronic, acute, sub-acute and abscess from various causes are included in the data, I have collected records of 1976 cases of dysentery including diarrhœa from the register of the Out-patient Department of the Campbell Hospital, Calcutta. These are the only figures available on the subject and represent the attendance from March, 1920 to December, 1922. I would like to emphasise the fact here that any very great reliance must not be put on the sweeping diagnosis that one is compelled to adopt in the Out-patient Department. Disorders of the bowels from various causes are included in the categories of dysentery and diarrhœa. As there is no special Hospital or wards here for the treatment of dysentery and diarrhœa, I had no other alternative than to depend on the cases that come to the Out-patient Department. Figues collected from Jails, as has been done by Sir Leonard Rogers for his book on Bowel Disease in the Tropics are not infallible as the chances of infection are great in a confined place vitiating the whole question of the incidence of the disease. So, for the present, the question of the seasonal incidence of bowel complaints is left open for future investigation.

The following meteorological data were taken from the Alipur Observatory, Calcutta :—

(*a*) Monthly total rainfall in inches.

(*b*) Monthly Mean Temperature. This is given by the Mean of Mean Maximum and Mean Minimum.

(*c*) Monthly Mean Humidity. This is given by the Monthly Mean of Humidity at 8 A.M., Hmidity at 10 A.M. and Humidity at 4 P.M.

The data are given in Table I for statistical purpose.

The subject will be discussed first from the clinical aspect and then the relationship between the different factors will be dealt with from the statistical point of view. The latter method of investigation is sometimes of utmost importance to find out the cause and effect in an illness. But unfortunately, this method is seldom resorted to in our medical and surgical literature and I hope, this paper will be an incentive for future work of this nature. I may, therefore, rightly claim pardon for the length of the paper as regards the statistical portion which illustrates the methods to be applied in such investigations.

By the surgeons and the gynœcologists the appendix is always looked upon with suspicion. The justification for its removal from the body, when an opportunity occurs, is its mischievous pranks.

TABLE I.

Month.	Appendicitis.	Dysentery.	Humidity.	Temperature.	Rainfall.	Month.	Appendicitis.	Dysentery.	Humidity.	Temperature.	Rainfall.
1920.						August.	6	65	88	82·8	16·82
March.	0	61	72	79·3	6·27	September.	7	48	85	83·1	6·35
April.	7	54	72	85·0	0·04	October	7	78	76	79·4	0·29
May.	4	51	68	87·0	2·61	November	6	78	67	72·2	0
June.	8	55	74	88·5	5·13	December	7	64	67	67·2	0
July.	5	48	88	83·8	14·47						
August.	13	62	85	83·6	18·66	1922.					
September.	4	93	83	83·8	9.36	January	7	68	62	66·6	0·17
October.	3	101	81	81·2	5·73	February	4	51	52	72·6	0
November.	10	82	69	73·9	0·02	March.	6	51	53	82·3	0·02
December.	7	92	63	65·6	0	April.	4	46	65	86·6	1·19
1921.						May,	8	32	71	87·6	2·47
January.	5	72	69	67·1	2·09	June.	14	32	88	83·2	22·89
February.	4	59	64	71·4	0·49	July.	9	46	88	83·7	14·50
March.	3	62	66	81·9	0·73	August.	10	36	87	83·2	18·11
April.	4	34	73	84·6	2·85	September.	12	51	88	82·4	21·42
May.	2	40	72	88·9	3·01	October.	6	53	77	79·0	2·24
June.	14	46	84	84·9	14·27	November.	6	70	68	73·1	0·09
July.	10	57	85	84·0	9·66	December.	4	48	68	66·2	0

The appendix is considered as a remnant structure in the human body having no function. This is open to question. The evolution theory teaches us that the vestigeal structures suffer most when the system is disordered. Again, for a large number of cases of gastric troubles the appendix has been held responsible. MacEwen thinks that the secretion of the appendix excites peristalsis of the cœcum or colon. Canal has stated that about 6 oz. of light straw-coloured fluid are daily secreted from an appendix. The argument put forward against the appendix having any function is the statement that a large number of people whose appendices have been removed remain well. Needless to say, that this argument is not convincing. It only proves that the appendix is not indispensible.

The appendix is liable to sudden inflammation on account of its anatomical peculiarities. We are still groping in the dark as regards the exact causation of such inflammation. I shall leave aside those cases for my purpose, where mechanical obstructions excite appendicular troubles. Foreign bodies in the appendix are comparatively rare; of course, I exempt fœcal concretions from this group.

The following is the list of causes that have been put forward as responsible for the appendicular troubles :—

FOODSTUFFS.

Fat, Meat, Bananas,[6] Chocolates, etc.

FOREIGN BODIES.

Iron particles or stonedust from rollers or grinders. Enamel chips from utensils. Tin, pins, needles, fish-bones, hair, grape-seeds, bits of bone, cherry stones, and fæcal concretions.

ENTOZOA.

Oxyuris vermicularis, Trichocephalus Dispar, Ascaris lumbricoides, Ecchinococcus.

DISEASES.

Dysentery, typhoid fever, influenza, tonsilitis, rheumatism dental caries, nasal sinusites, measles, scarlet fever, mumps and T. B.

OTHER CAUSES.

Trauma, obstruction of the blood supply from kinks and tumours, adhesions, intestinal stasis from want of sufficient amount of cellulose in the modern human diet and the action of the right psoas muscle.

From a study of 183 cases mentioned in this article of appendicular troubles of various nature in Bengal and from experience of similar cases in the Punjab and the North Western Frontier Provinces I am led to believe that the primary cause of appendicitis is to be sought for in the disorders of the cæcum or the colon. The importance of this factor has not been sufficiently recognised by writers on this subject. In India the conditions are different from those of other countries and the incidence of appendicitis receives a special significance when we consider the immense difference in the habits of the people of the different provinces, their susceptibility to certain endemic intestinal diseases and the wide range of climatic changes.

I shall classify my cases into three groups according to the presence or absence of the history of gastro-intestinal troubles. My investigation is based on the observations of cases in the operation room, post-mortem room and the pathological room.

(1) Cases of appendicitis in which the history of gastro-intestinal trouble is not clear.

(2) Cases of appendicitis attended with an acute history of colitis, dysentery, constipation, diarrhœa or indigestion.

(3) Cases of appendicitis with a previous or chronic history of colitis, dysentery, constipation, diarrhœa and indigestion.

Out of 183 cases there was no operative procedure adopted in 58 and their appendices could not be examined. In the remaining 125 cases the distribution was as follows :—

Group 1. Without any assignable gastro-intestinal cause ... ... 42·2%

Group 2. Attended with a history of acute gastro-intestinal troubles ... ... 22·8%

Group 3. Having chronic or previous history of gastro-intestinal complaints 35%

I cannot for a moment think that the ingenious theories put forward from time to time regarding the various articles of human diet being responsible for the occurrence of appendicular troubles would stand the test of criticism. In India there are different classes of people belonging to different nationalities and religion and their diet varies a good deal. The Punjabi, the people of the North Western Frontier Province as well as the Bengali do not take any preserved foodstuff. Generally speaking rice, vegetables and fish are the staple diet of the Bengali. Meat is seldom taken by them. The diet of the Punjabi consists of flour from wheat, vegetables and *dal* or cooked cereals. Sometimes meat is taken. Fish is not available always. The subsistence of the people of the North Western Frontier Province is bread and meat (especially amongst the city dwellers) and sometimes vegetables. Lard is religiously avoided by the Hindus unless it is taken with the adulterated *Ghee*. My general impression is that appendicitis is more common in Bengal than in the other two Provinces and more frequent in the cities than in the villages, where the people live under more healthy conditions. Of course a more careful record is kept in the cities with hospitals than in the villages where many cases go undiagnosed and untreated.

The number of foreign bodies found in the appendix was extremely small when we consider the wide prevalence of the disease. In the few cases where solid bodies were detected almost all of these were of fæcal origin and consisted of food debris and the secretions from the lumen. In the Group I, 15 cases were found with foreign bodies; out of this, fishbone was seen sticking inside the lumen in one case and the tip of a chilli in another. The remaining 13 cases had fæcal concretions, some of which were of semi-solid consistency. Oxyuris vermicularis was found in two cases with the concretions. The fæcal concretions may be regarded as the immediate exciting causes of appendicitis. But predisposing conditions must exist before such enteroliths will form.

Normally, the fæcal matter may pass into the appendix as could be seen under X-rays with barium salts. Strön considers that it is possible to visualise about 90% of appendices. Owing to its muscular coat the appendix may be seen slowly to twist and turn. In the anthropoids and children it has been found that the fæcal contents of the cæcum pass freely into the appendix. In the gibbon seeds of fruit as big as cherrystones are found inside the appendix during normal meal.[2] Under certain pathological conditions the egress of the liquid fæcal matter from inside the appendix may be stopped and by a gradual absorption of the watery fluid deposits of salts and debris take place and concretions form, which in time may devitalise the structures and cut off the circulation. The normal circulation of the fæcal matter may be obstructed either from some external or internal causes. The internal causes may be an interference in the action of the valve of Garlech or an inflammatory state of the mucous membrane of the lumen. The inflammation may be so slight at first as to merely occlude the lumen without producing any definite clinical signs till the inspissated fæcal matter or concretions produce ulceration or light up the growth of micro-organisms. Sometimes violent irregular spasms of the musculature of the lumen produces colic which may be referred to other parts of the abdomen. The appendix itself insensible becomes sensitive through its adjacent ileal mesentery. The mere presence of a concretion in an appendix may not necessarily give rise to trouble, perhaps so long as it is not jammed inside the lumen or as long as its movement is not impeded or produce inflammation. In the dissection room it is not uncommon to find such concretions where there had been no history of any appendicular trouble before death. Sometimes one or more stones are met with in the appendix. They are more or less round or oatlike and are unlike facetted gall-stones. The product of the inflammation becomes in time purulent and the appendix may be distended with pus which does not find its exit into the cæcum on account of obstruction in the lumen. The incomplete attachment of the meso-appendix is conducive to congestion and ulceration of the appendix in its distal portion. Hence it is generally found that the ulceration is not exactly over the concretion but is distal to it.

Colitis and dysentery are very common in India. The lesions of dysentery and colitis are situated either in the colon or the cæcum or in both. The mucosa of the appendix is continuous with that of the cæcum. Anatomically the appendix shows the same structure as the cæcum or colon. In monkeys the cæcum terminates in a blunt point. Cases of appendicitis have been reported to have been observed in anthropoids when they are put on human diet.[3] It is plausible to think that a diet or a pathological lesion which affects the cæcum may also affect the appendix. Now the problem is whether the appendix is affected first or whether the inflammation is secondary to the affection of the cæcum. Both are possible. Histologically the appendix abounds with lymphoid follicles and with relatively extensive epithelial membrane. It is called an abdominal tonsil. An infection may be quite innocuous to the cæcum but it may be dangerous to the appendix. Evans has observed an increase in the incidence of appendicitis during an epidemic of sorethroat and tonsilitis. The existence of the elective affinity of the streptococci for the appendix has lately been proved.[5] The appendix may thus be also affected primarily and in such cases an apparent assignable cause may be wanting.

In my series of cases of appendicitis under Group I having an unknown cause streptococci, staphylococci and colon bacilli were found on culture from the smear of the mucous membrane of the lumen. The inflammation noticed was of varying degrees affecting the mucous membrane and the peritoneum.

In 5 cases there were characteristic signs of dysentery. Amæba was discovered inside the lumen of the appendix and also in the stools. In two cases there were multiple perforations in the appendices as well as in the cæcum. The perforations were situated posteriorly. The tenderness was more extended towards the lumbar region. This extension of tenderness towards the back is very often noticed in dysenteric affection and may be mistaken for appendicitis of the retro-colic variety. Post colic abscess may form with or without perforation. As the dysenteric lesion may affect the ascending colon the tenderness may reach the kidney region behind and the region of the gall bladder in front. The sequelæ of a healed dysenteric ulcer are adhesions, cicatrices and puckering of the structures. The resulting mass which is often felt in the iliac region may be mistaken for appendicular thickening. During a simple appendicectomy the interior of the cæcum cannot be inspected and so the existence of the similarity of the pathological conditions cannot be established. Sometimes the thickening of the cæcum can be felt and extensive adhesions are noticed when the abdomen is opened. In two cases I have found extensive gangrenous conditions of the cæcum, ascending colon, and the appendix. In one case I have found tubercular lesion of the cæcum and the appendix.

35% of the total cases gave a chronic history of gastro-intestinal troubles such as colitis, dysentery, alternate diarrhœa and constipation. In 22·8% of cases either colitis, dysentery, diarrhœa or constipation was associated with appendicular troubles. In the majority of cases attacks of indigestion after a feast or an indigestible meal accompanied by diarrhœa preceded the attack of appendicitis. It is also a notable fact that many patients give history of sudden pain in the abdomen attended with nausea or vomiting in the early part of the morning while they have been lying or sleeping in their beds, *i.e.*, 6 to 12 hours or so after a meal. Any irritation whether of a chemical or a pathological nature which affects the cæcum may with equal or aggravated intensity affect the appendix. Sometimes after an appendicectomy there is troublesome diarrhœa. Whenever the patients refused an operation or an operation was postponed on surgical grounds a routine treatment of bowel wash with warm boric lotion twice daily, warm compress over the area of tenderness and a restricted liquid diet were adopted. Many tided over the imminent danger from such simple procedures following the improvement of the bowel. Emetin was tried with success when amœbic infection was suspected. It was tried in those cases where amoeba was discovered in the stool or in the appendix after operation or where the clinical signs of dysenteric affection were present. Rogers[4] is of opinion that the typical dysenteric symptoms may be altogether absent in some cases of amœbic infection and diarrhœa may be the only symptom. There may be present alternate diarrhœa and constipation. The site of an old dysenteric lesion is very vulnorable to other infections. The negative findings of amæba in stool do not always indicate the absence of infection. Frequently, the accompanying bowel troubles may be only a recrudescence of the old infection of the intestine.

In children gastro-intestinal trouble such as enteritis is of more importance in the causation of appendicitis than any other factor. In these cases the lesion generally starts from the distal extremity of the appendix. The greatest difficulty may be experienced in the diagnosis of appendicitis in children.

The prevalence of the disorders of the lower bowel in India is increased during the monsoon and in the autumn months. The majority of the bowel complaints on the advent of the monsoon are due to dysentery. The experience of Sir Leonard Rogers[4] is that these are of amœbic nature. According to him the incidence of dysentery is most marked from the latter half of June to October. I have found that the largest number of appendicular troubles also occur during these months.

The Fig. I shows monthly relationship between Appendicitis, Rainfall, Mean Humidity, Mean Temperature and Bowel complaints (Dysentery and Diarrhœa).

The Fig. II represents graphically the seasonal relationship between Appendicitis and Rainfall. Winter—December, January and February, Spring—March, April and May, Summer—June, July and August, Autumn—September, October and November.

The Fig. III shows the sex incidence of appendicitis among different nationality. In the case of Hindus and Mahommedans males are proportionately affected to a greater extent than the females and the ratio of males to females is widely different from that of the Europeans, Anglo-Indians and other classes, *e.g.*,

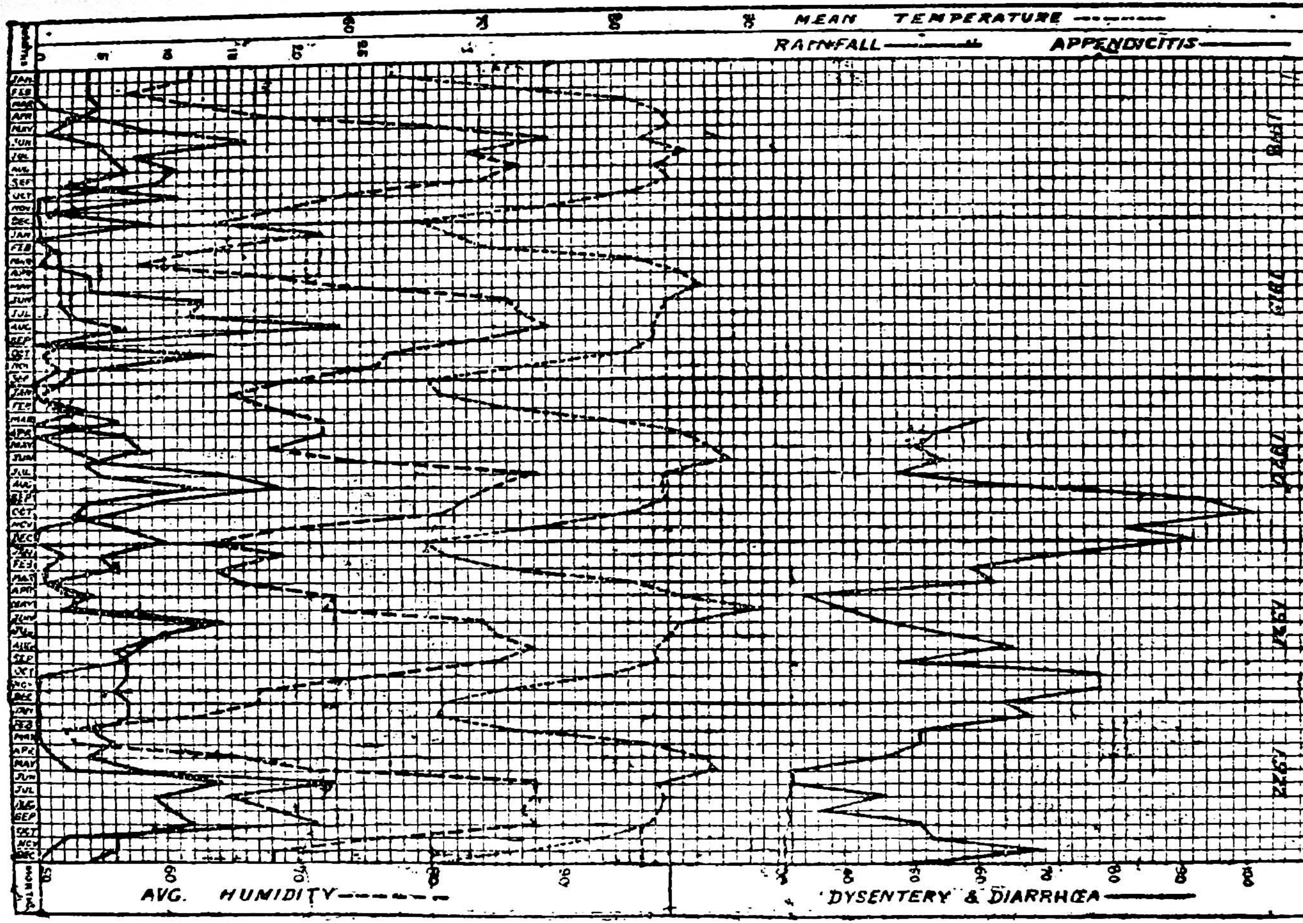

FIG. I.—Monthly relationship between Appendicitis, Rain fall. Mean Humidity, Mean Temperature and Bowel complaints.

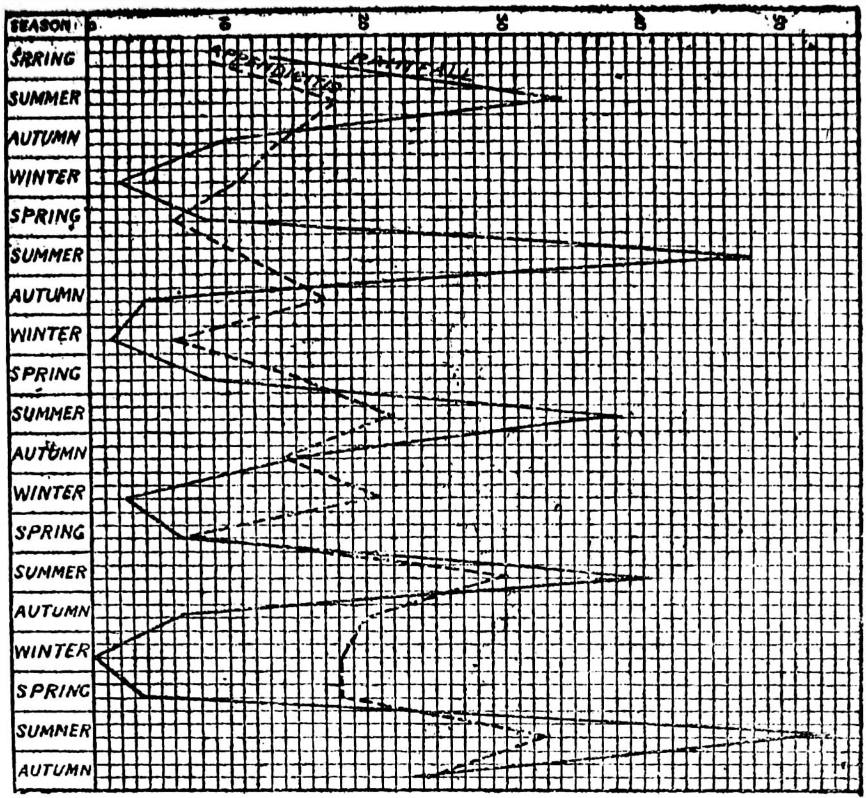

FIG. II.—The Seasonal Relationship between Appendicitis and Rainfall.

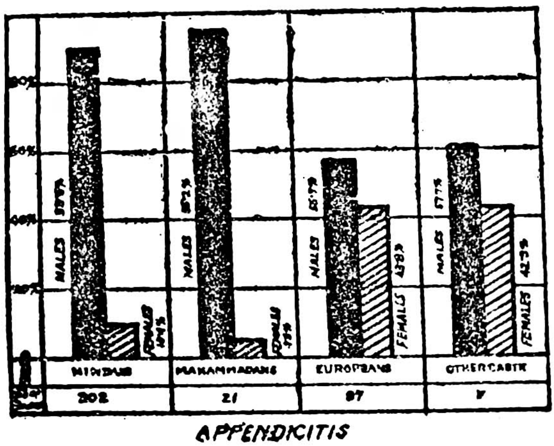

FIG. III.—The sex incidence of Appendicitis among different nationality.

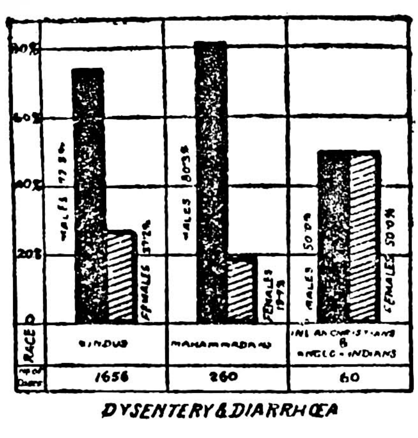

FIG. IV.—The sex incidence of Dysentery and Diarrhœa.

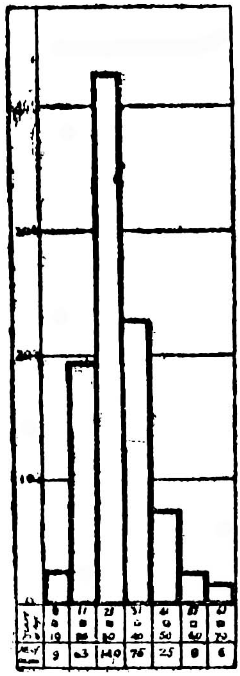

FIG. V.—The incidence of Appendicitis.

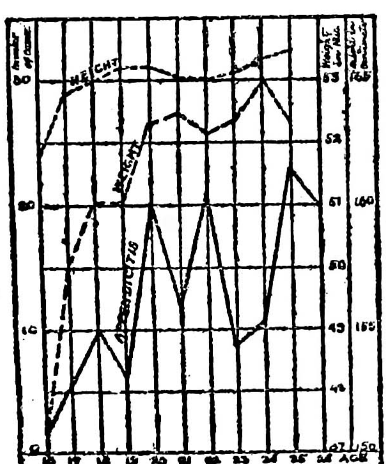

FIG. VI.—The curve of development of the Indians in weight and height and the number of cases of Appendicitis affected at different ages.

Chinese, Jews, etc. The ratio in the latter classes tallies with the findings of other workers on the subject.

The Fig. IV represents the sex incidence of Dysentery and Diarrhœa. Here also we find the females are comparatively less affected than the males in the case of the Hindus and Mahommedans. Rogers is of same opinion.

An argument may be put forward that the females of the Hindus and the Mahommedans do not readily take admissions into a Hospital for their treatment. But whether this factor alone would explain the wide difference in incidence is more than I can say definitely.

The Fig. V shows the age incidence of Appendicitis. The largest number is affected between 21 and 30 years of age.

The Fig. VI shows the curve of development of the Indians in weight and height and the number of cases of appendicitis affected at different ages. The curve of development is taken from the reports of the Student Welfare Committee of the University of Calcutta and is based on the investigation of about 6,000 students. The maximum development is completed at about 21 years. The curve for appendicitis reaches the maximum height at about the same age.

LEUCOCYTIC COUNT IN APPENDICITIS.

As in all other infections the leucocytes increase in number in appendicitis. There is a disposition to lay special stress on the presence of leucocytosis as an index of the severity of the infection and also as an aid to differential diagnosis. The variability of the leucocyte counts is in my experience so wide that no reliance could be placed on this factor alone. The increase of W. B. C. depends on (1) the resistance of the patient, (2) the amount of toxin absorbed and (3) the type of the infection. The total W. B. C. count varied from 5,000 to 37,000 in my cases and gave no indication of the gravity of the case. Patients with 5,000 to 7,500 W. B. C. succumbed and a gangrenous condition of the appendix and the ascending colon was found on *post-mortem* examination. While with 37,000 W. B. C. patients have recovered without operation. Subsequent operation showed only external adhesions and cicatrices inside the lumen. There is a ready explanation to meet these two extreme cases. The low count is supposed to be due to the depressed vitality and the high count is an evidence of increased resistance.

The leucocyte count is very deceptive in estimating the extent of the inflammatory process. So a decision for an operative interference cannot be made by simply estimating the number of W. B. C. The count is comparatively low in appendicular trouble of the amœbic variety. If it ranges from 5,000 to 15,000 there should be strong suspicion of amœbic infection. In a series of 20 liver abscess cases where I made blood counts I observed that the leucocytes generally varied from 9,000 to 20,000 in the amœbic variety and were over 20,000 in cases due to the streptococci and coli infection. The low degree of leucocytosis in the amœbic variety of appendicitis may sometimes be due to the varying degree of anæmia from chronic dysentery. In places where malaria and kala-azar are prevalent as in Bengal great care is required in interpreting the blood counts. The relative count may be high although the total W. B. C. count only will show a low figure. The polymorphonuclear variety remains near about 70%. Generally the pus is thinner and more copious in quantity with high counts than with low counts of W. B. C. in appendicular abscess.

Regarding the prognosis it has been held that a low count (5,000 to 12,000) in the presence of grave symptoms is always a danger signal. In higher leucocyte count (20,000 to 40,000) in the absence of grave symptoms the prognosis is not bad. Such patient may recover completely.

While speaking about the leucocytosis in appendicular troubles I intend to draw special attention to the case of female patients. As is well known appendicitis in them may be associated with troubles of the tube and ovary. The blood count may be misleading. Appendicitis in a menstruating female will give a very deceptive high count. The W. B. C. may reach up to 40,000 without any very serious involvement of the appendix. This I have noticed in a couple of cases where the leucocytosis went up to 37,000. This led me to do the blood count in a large number of female patients during their menstrual period. The W. B. C. rises steadily from the time of congestion till the maximum reaches on the second day of the flow. It is no wonder that an appendicular attack at this time will give a higher count.

CONCLUSIONS FROM THE CLINICAL ASPECT—

(1) It would appear that the majority of cases of appendicular troubles in India may be traced to the disorders of the lower bowel and is secondary to them. Colitis and dysentery are the common complaints responsible for appendicitis.

(2) The amœbic variety of dysentery is the most prevalent one. Emetin is of great value and attention to the lower bowels is necessary for the treatment of appendicular troubles.

(3) There is apparent relationship between Appendicitis, Rainfall and bowel complaints.

(4) The value of W. B. C. count in appendicitis must not be overrated for our diagnostic purpose and for prognosis.

(5) As there is a discrepancy between the conclusions derived from statistical and clinical findings as regards the co-relationship of dysentery and appendicitis further observation is necessary to establish the point definitely. The discrepancy may be traced to the defective dysentery data.

Part II.

SCOPE OF THE ENQUIRY.

I ought to make it quite clear that my enquiry is strictly limited to an investigation of the *statistical* relationships subsisting between the different varieties and my results are definite of a statistical nature. I believe my results possess considerable medical significance but I do not think immediate medical inferences will be justified.

I should also state my results are tentative and provisional. Analysis of more numerous data, (*i*) spread over a larger number of years and (*ii*) collected from many different localities, will be required to arrive at definite conclusions. At the same time I would like to point out that even tentative results deserve careful study. My chief objective in undertaking the present analysis has been to draw attention to the need for pressing into service the powerful tools developed by the Biometric School (under the leadership of Karl Pearson) in breaking new ground and opening new fields for medical research.

SECTION I. SMOOTHING (Table 2 & 3).

Consider the curve for Dysentery. Two things appear quite clearly. There is a slight downward trend indicating a small steady decline with time. There is also a very well marked seasonal fluctuation. I shall use the phrase "secular change" to include both the above variations, while I shall use the term "secular trend" in a restricted sense to denote the steady decline (or growth) with time and the phrase "seasonal variation" to denote the periodic fluctuation.

THE SECULAR CHANGE.

As Pearson points out ("On the Variate Difference Method," Biometrika 1923, XIV p. 281) "the data rise and fall with apparent, but not indeed necessary irregularity, above and below a sort of average curve representing the secular change." The actual problem of determining this average curve presents considerable practical difficulties. Our aim is to remove the sudden and apparenly accidental irregularities present in the material and yet at the same time reproduce the fluctuations inherent in the secular change. The only method available is to fit a smooth curve to the given data and then by visual comparison of the graduated curve against the observational curve judge the closeness of fit as well as the smoothness achieved. If the fit is too close it will reproduce many of the accidental irregularities, on the other hand if the graduated curve is too smooth it will miss some of the fluctuations inherent in the secular change. We must try to strike a happy mean between the two extremes. No reliable criterion is available and the whole process is largely one of trial and error.

For the general smooth, I adopted the continuous curve method of graduation described by E. C. Rhodes in Tracts for Computors VI. Smoothing (Cambridge University Press, (1923). After repeated trials with 5 point and 7 point curves I finally decided to work with a 15 point 4th order parabola. The results are shown in Col. (*iii*) of Tables 2 and 3. The differences between the actual values and the graduated values are given in Col. (*viii*) of the same tables. The curves are shown plotted as graphs in diagram 1.

The smoothness achieved is of course satisfactory. The closeness of fit also is not bad. The root mean square difference (*i.e.* the square root of the mean of the squares of the differences between original data and smoothed values) is 13·17 for Dysentery and 2·891 for Appendicitis. It should be noted however that the 14 end-points (7 at each end) have been graduated by a different formula and are not equally satisfactory. Omitting the end points the root mean square difference is 10·17 and 2·821 respectively, indicating a much better fit in the interior of the curves and specially so in the case of Dysentery.

SEASONAL VARIATION.

We may proceed in a totally different way. We can obtain the monthly averages and assume that such monthly averages give the normal values for the different months. The monthly averages are shown in Col. (*iv*) of Tables 2 & 3. The closeness of fit is quite good; it is much better that the general smooth, the root mean square difference being now during 34 months, 11·92 for Dysentery and 2·205 for Appendicitis and in 20 months 9·75 and 1·904 respectively.

The smoothness however is not very satisfactory since owing to the smallness of the total number of months the crude averages show considerable irregularities. We may try to remove them by fitting a smooth curve to the crude averages themselves.

For Dysentery the 15 point summation method of Woolhouse (described in the tract on Smoothing) gives good results, while for appendicitis a 7 point continuous curve (Rhodes's method) works well. The values are shown in Col. (*v*) of Tables 2 and 3. The r. m. s. differences are 12·75 and 2·652 with 34 months and 12·03 and 2·265 with 20th months. The fit is naturally worse than crude averages but the smoothness achieved is better.

As an alternative method I first eliminated the steady change with time by fitting suitable straight lines to the given data. I found that the lines of best fit (*i.e.* the lines of regression) were for :—

Dysentery : $y = 68{\cdot}75 - 0{\cdot}63x$

Appendicitis : $y = 5{\cdot}23 + 0{\cdot}086x$.

where x = the serial number of the month.

The straight lines are shown in diagram.

Subtracting the secular trend we obtain the monthly residuals. Averaging and smoothing these residuals we get the smoothed fluctuations adding which to the secular trend we finally get the graduated monthly values.

For Dysentery they are shown in Col. (*vi*) Table 2. The smooth is good while the closeness of fit is much better than with even the crude average curve. The r. m. s. difference is 8·57 for 34 months and 0·29 for 20 months showing that the fit at the tails are now even better than the fit in the interior. For Appendicitis the fit is worse than the 7-point graduated average, hence I have not thought it necessary to reproduce the actual figures.

As a last alternative I have obtained the complete Fontier series for the crude averages. They are given below.

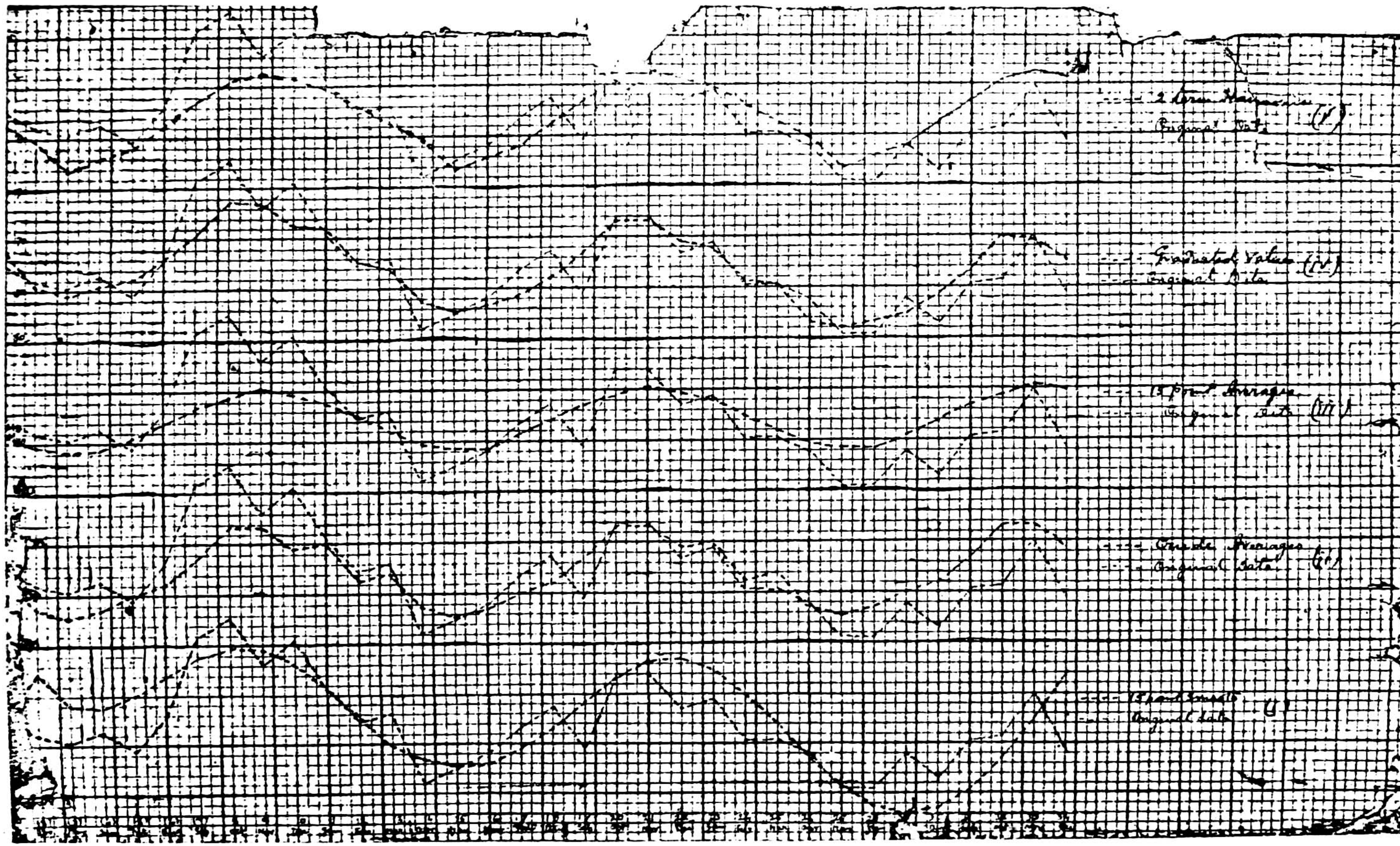
Graduated Values (IV)
Original Data
15 Point Averages
Original Data (III)
Crude Averages
Original Data (II)

Diagram I.

DESENTERY:

$$D = 58{\cdot}55 + 10{\cdot}95 \cos x - 1{\cdot}80 \cos 2x - 1{\cdot}67 \cos 3x + 1{\cdot}93 \cos 4x + 2{\cdot}25 \cos 5x + 1{\cdot}37 \cos 6x - 11{\cdot}83 \text{ Sin } x + 0{\cdot}19 \text{ Sin } 2x + 1{\cdot}60 3x - 1{\cdot}05 \text{ Sin } 4x - 3{\cdot}58 \text{ Sin } 5x$$

APPENDICITIS:

$$A = 6{\cdot}56 - 2{\cdot}21 \cos x + 1{\cdot}37 \cos 2x + 0{\cdot}01 \cos 3x - 0{\cdot}49 \cos 4x + 1{\cdot}18 \cos 5x - 0{\cdot}88 \cos 6x - 1{\cdot}03 \text{ Sin } x - 0{\cdot}79 \text{ Sin } 2x + 0{\cdot}05 \text{ Sin } 3x - 0{\cdot}45 \text{ Sin } 4x + 1{\cdot}08 \text{ Sin } 5x$$

In the case of Dysentery the first harmonic term is much more prominent than the others indicating a fairly simple type of periodicity. With Appendicitis on the other hand the higher terms remain quite appreciable showing that the periodicity is rather complicated.

Taking the first or say the first and the second harmonic terms we obtain new graduations. They are given in Col. (*vi*), Table 2 and Col. (*v*), Table 3. The curves are of course quite smooth. The r. m. s. differences are 12·34 and 2·588 for 34 months and 10·63 and 2·157 for 20 months. For Dysentery the fit is thus better than the general smooth and the 15-point average but worse than the crude average and the secular graduation. For Appendicitis it is better than all the different smooths except the crude average.

We shall therefore be justified in using them as alternative graduation. I should however point out that there is no special sanctity attached to this method.

RAINFALL, HUMIDITY AND TEMPERATURE.

Reliable normals are available which supply full information about seasonal variations. Smoothing is no longer necessary.

For the sake of completeness I append below the Fourier expressions for normal Rainfall, Humidity and Temperature.

$$R = 5{\cdot}21 - 6{\cdot}52 \cos x + 1{\cdot}81 \cos 2x + 0{\cdot}23 \cos 3x - 0{\cdot}48 \cos 4x + 0{\cdot}20 \cos 5x - 0{\cdot}12 \cos 6x - 0{\cdot}86 \sin x + 0{\cdot}95 \sin 2x + 0{\cdot}57 \sin 3x - 0{\cdot}46 \sin 4x - 0{\cdot}11 \sin 5x$$

$$H = 76{\cdot}6 - 9{\cdot}4 \cos x + 1{\cdot}3 \cos 2x + 0{\cdot}5 \cos 3x + 0{\cdot}7 \cos 4x + 0{\cdot}4 \cos 5x - 0{\cdot}1 \cos 6x - 4{\cdot}8 \sin x + 0{\cdot}6 \sin 2x - 0{\cdot}3 \sin 3x - 0{\cdot}6 \sin 4x + 0{\cdot}4 \sin 5x$$

TABLE 2.

(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)
							Differences between original data and smoothing.				
Month.	Original Data.	15 point smooth.	Crude Averages.	15 Point Averages.	Graduated Values.	2 term Harmonic.	15 Point smooth.	Crude Averages.	15 Point Averages.	Crude Averages.	2 term Harmonic.
March 1920	... 61	63·3	58·0	53·5	65·5	55·2	−2·3	+3·0	+7·5	−4·5	+5·8
	... 54	78·5	44·7	48·5	52·2	48·6	−24·5	+9·3	+5·5	+1·8	+5·4
	... 51	66·2	41·0	46·9	48·4	37·2	−15·2	+10·0	+4·1	+2·6	+13·8
	... 55	65·0	44·3	47·3	51·7	42·4	−10·0	+10·7	+7·7	+3·3	+12·6
	... 48	70·2	50·3	51·5	54·4	45·8	−22·2	−2·3	−3·5	−6·4	+2·2
	... 62	77·9	54·3	57·7	61·7	54·6	−15·9	+7·7	+4·3	+0·3	+7·4
	... 93	84·9	64·0	64·1	71·4	64·4	+8·1	+29·0	+28·9	+21·6	+28·6
	... 101	89·0	77·3	68·3	84·7	72·2	+12·0	+23·7	+32·7	+16·3	+28·8
	... 82	88·3	76·7	71·1	84·0	75·0	−6·3	+5·3	+10·9	−2·0	+7·0
	... 92	82·4	68·0	69·4	75·3	72·6	+9·6	+24·0	+22·6	+16·8	+19·4
January 1921	... 72	72·2	70·0	65·7	73·8	68·8	−0·2	+2·0	+6·3	−1·2	+3·2
	... 59	60·2	55·0	59·5	59·8	61·5	−1·2	+4·0	−0·5	−0·8	−2·5
	... 62	49·5	58·0	53·5	58·0	55·2	+10·5	+4·0	+8·5	+4·0	+6·8
	... 34	43·8	44·7	48·5	44·7	48·6	−9·8	−10·7	−14·5	−10·7	−14·6
	... 40	41·0	41·0	46·9	40·9	37·2	−1·0	−1·0	−6·9	−0·9	+2·8
	... 46	42·4	44·3	47·3	44·2	42·4	+3·6	+1·7	−1·3	+1·8	+3·6
	... 57	47·8	50·3	51·5	46·9	45·8	+9·2	+6·7	+5·5	+10·1	+11·2
	... 65	55·7	54·3	57·7	54·2	54·6	+9·3	+10·7	+7·3	+10·8	+10·4
	... 48	67·4	64·0	64·1	63·9	64·4	−19·4	−16·0	−16·1	−15·9	−16·4

(Table 2 Contd.)

(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)
							Differences between original data and smoothing.				
Month.	Original Data.	15 Point smooth.	Crude Average.	15 Point smooth.	Original Data.	2 term Harmonic.	15 Point Smooth.	Crude Averages.	15 Point Average.	Graduated Values.	2 term Harmonic
...	78	77·3	77·3	68·3	77·2	72·2	+ 0·7	+ 0·7	+ 9·7	+ 0·8	+ 5·8
...	78	83·1	76·7	71·1	76·5	75·6	− 5·1	+ 1·3	+ 6·9	+ 1·5	+ 3·0
...	64	83·9	68·0	69·4	67 8	72·6	−19·9	− 4·0	− 5·4	− 3·8	− 8·6
January ...	68	79·4	70·0	65·7	66·2	68·8	−11·4	− 2·0	+ 2·3	+ 1·8	− 0·8
1922 ...	51	70·3	55·0	59·5	52·2	61·5	−19·3	− 4·0	− 8·5	− 1·2	−10·5
...	51	58·0	58·0	53·5	50·5	55·2	− 7·0	− 7·0	− 2·5	+ 0·5	− 4·2
...	46	44·6	44·7	48·5	37·2	48·6	+ 1·4	+ 1·3	− 2·5	+ 8·8	− 2·6
...	32	32·8	41·0	46·9	33·8	37·2	− 0·8	− 9·0	−14·9	− 1·8	− 5·2
...	32	24·8	44·3	47·3	37·1	42·4	+ 7·2	−12·3	−15·3	− 5·1	−10·4
...	46	21·6	50·3	51·5	39·8	45·8	+24·4	− 4·3	− 5·5	+ 6·2	+ 0·2
...	36	23·9	54·3	57·7	47·1	54·6	+12·9	−18·3	−21·7	−11·1	−18·6
...	51	31·5	64·0	64·1	56·8	64·4	+19·5	−13·0	−13·1	− 5·8	−13·4
...	53	43·9	77·3	68·3	70·1	72·2	+ 9·1	−24·3	−15·3	−17·1	−19·2
...	70	59·9	76·7	71·1	69·4	75·0	+10·1	− 6·7	− 1·1	+ 0·6	− 5·0
...	48	77·5	68·0	69·5	61·0	72·6	−19·5	−20·0	−21·5	−13·0	−24·6
Root Mean Sq. Deviation (34 months)							13·17	11·92	12·75	8·57	12·34
,, ,, ,, ,, (20 months)							10·17	9·75	12·03	9·29	10·63

TABLE 3. APPENDICITIS, RESULT OF SMOOTHING.

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
						Differences between original date and smoothing.				
Month.	Original Data.	15 point Smooth.	Crude Averages.	7 point Averages.	z-term Harmonic		15 Point smooth.	Crude Averages.	7 Point Averages.	2 term Harmonic.
1920										
March	... 0	2·4	3·0	3·1	3·2		− 2·4	− 3·0	− 3·1	− 3·2
	... 7	3·6	5·0	3·8	4·2		+ 3·4	+ 2·0	+ 3·2	+ 2·8
	... 4	5·2	4·7	6·4	6·8		− 1·2	− 0·7	− 2·4	− 2·8
	... 8	6·6	12·0	9·6	9·2		+ 1·4	− 4·0	− 1·6	− 1·2
	... 5	7·6	8·0	10·1	10·1		− 2·6	− 3·0	− 5·1	− 5·1
	... 13	8·1	9·7	9·7	9·0		+ 4·9	+ 3·3	+ 3·3	+ 4·0
	... 4	8·2	9·7	7·3	7·2		− 4·2	− 3·7	− 3·3	− 3·2
	... 3	8·1	5·3	5·3	6·2		− 5·1	− 2·3	− 2·3	− 3·2
	... 10	7·5	7·3	4·9	6·4		+ 2·5	+ 2·7	+ 5·1	+ 3·6
	... 7	6·6	6·0	6·2	6·5		+ 0·4	+ 1·0	+ 0·8	− 1·5
1921										
January	... 5	5·4	6·0	5·5	5·7		− 0·4	− 1·0	− 0·5	− 0·7
	... 4	4·5	4·0	3·9	4·1		− 0·5	0·0	+ 0·1	− 0·1
	... 3	3·9	3·0	3·1	3·2		− 0·9	0·0	− 0·1	− 0·2
	... 4	4·0	5·0	3·8	4·2		0	− 1·0	+ 0·2	− 0·2
	... 2	4·4	4·7	6·4	6·8		− 2·4	− 2·7	− 4·4	− 4·8
	... 14	5·4	12·0	9·6	9·2		+ 8·6	+ 2·0	+ 4·4	+ 4·8
	... 10	6·4	8·0	10·9	10·1		+ 3·6	+ 2·0	− 0·9	− 0·8
	... 6	7·2	9·7	9·7	9·0		− 1·2	− 3·7	− 3·7	− 3·0

(*Table 3. Contd.*)

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
						Differences between original date and smoothing.				
Month.	nal Data.	15 Point Smooth.	Crude Averages.	7 Point Averages.	2-term Harmonia.		15 Point Smooth.	Crude Averages.	7 Point Averages.	2 term Harmonic.
	... 7	7· 8	7· 7	7· 3	7· 2		− 0· 8	− 0· 7	− 0· 3	− 0· 2
	... 7	8· 0	5· 3	5· 3	6· 2		− 1· 8	+ 1· 7	+ 1· 7	+ 0· 8
	... 6	7· 9	7· 3	4· 9	6· 4		− 1· 9	+ 1· 3	+ 1· 1	− 0· 4
1922	... 7	7· 7	6· 0	6· 2	6· 5		− 0· 7	+ 1· 0	+ 0· 8	+ 0· 5
January	... 7	7· 5	6· 0	5· 5	5· 7		− 0· 5	+ 1· 0	+ 1· 5	+ 1· 3
	... 4	7· 4	4· 0	3· 9	4· 1		− 3· 4	0	+ 0· 1	− 0· 1
	... 6	7· 2	3· 0	3· 1	3· 2		− 1· 2	+ 3· 0	+ 2· 9	+ 2· 8
	... 4	7· 2	5· 0	3· 8	4· 2		− 3· 2	− 1· 0	+ 0· 2	− 0· 2
	... 8	7· 2	4· 7	6· 4	6· 8		+ 1· 5	+ 3· 3	+ 1· 6	+ 1· 2
	... 14	8· 0	12· 0	9· 6	9· 2		+ 6· 0	+ 2· 0	+ 4· 4	+ 4· 8
	... 9	8· 5	8· 0	10· 9	10· 1		+ 0· 5	+ 1· 0	− 1· 9	− 1· 1
	... 10	8· 8	9· 7	9· 7	9· 0		+ 1· 2	+ 0· 3	+ 0· 3	+ 1· 0
	... 12	8· 9	7· 7	7· 3	7· 2		+ 3· 1	+ 4· 3	+ 4· 7	+ 4· 8
	... 6	8· 5	5· 3	5· 3	6· 2		− 2· 5	+ 0· 7	+ 0· 7	− 0· 2
	... 6	7· 5	7· 3	4· 9	6· 4		− 1· 5	− 1· 3	+ 1· 1	− 0· 4
	... 4	5· 6	6· 0	6· 2	6· 5		− 1· 6	− 2· 0	− 2· 2	− 2· 5
			Mean root square deviation=				2·891	2·205	2·652	2·588
			20 term M. R. S. deviation=				2·821	1·904	2·265	2·157

In the case of Dysentery and Appendicitis I shall use the different graduations as substitutes for the true normals.

The above analysis shows that the monthly values and fluctuations of each variate are made up of a number of different factors.

SECULAR TREND.—First of all there is the steady secular change. In the case of Appendicitis it is a slight increase and in the case of Dysentery a slight decrease with time. In the case of the meteorological elements there is no appreciable steady change with time.

SEASONAL VARIATION.—We have seen that all the variates show marked seasonal fluctuations. These seasonal fluctuations are given by the respective normals or where the latter are not available by the averages crude or graduated.

DEPARTURES.—The change of a variate from month to month is another important quantity. They are given by the first differences. For example if A_1, A_2, A_3, A_4, be a series of monthly values then $dA_3 = A_3 - A_1$, ... is the series of first differences. The change of change will be given by the second difference which are written $d^2A_1 = dA_1 - dA_2$, $d^2A_2 = dA_2 - dA_3$, In general the nth differences will be represented by

$$d^n A_1 = d^n A_1 - d^{n-1} A_2, \quad d^n A_2 = d^{n-1} A_2 - d^{n-1} A_3 \text{ and Soon.}$$

If the secular trend can be represented adequately by a parabola of the nth order in time then obviously the time factor will be eliminated if we proceed to take the nth differentials. Working with finite differences instead of differentials the same result is approximately reached by taking the nth differences. But the result is only approximate and circumstances (such as the presence of short-periodic terms) may exist which would render the process invalid. This necessitates critical examination of the material. In the case of the present material we have not been able to detect any disturbing factor of importance.

SECTION II.
CORRELATIONAL METHODS AND NOTATIONS USED IN ANALYSIS.

The correlation between two variates measures the degree of association between the two variates. The co-efficient of correlation is zero if the variates are absolutely independent and it takes the value unity (positive or negative) if one variate is a function of the other *i.e.* is completely determined by the other. Between these values zero and unity the co-efficient of correlation can take every numerical value. This value provides, (*i*) a conceptual routine showing that certain phenomena are associated with certain other phenomena within a measured degree of uniformity of sequence and (*ii*) "a measure of the possible or probable deviation from this routine, which is a guide to the amount of variation in experience."*

The correlation between A and B will be written as r(A B), and the following abbreviations will be used throughout. A—Appendicitis, D—Dysentery, R—Rainfall, H—Humidity and T—Temperature. Thus r(D, H) is the correlation between Dysentery and Humidity.

Average values (and Normals) are usually written with a bar on the top. Successive monthly values are written in the following way. If H_1 is the Humidity in any one month then H_2 will denote the Humidity in the next month, H_3 the Humidity in the third month, and so on H_n being the Humidity in the *n*th month. The co-efficient of correlation has been calculated in every case by the product moment method.†

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*Karl Pearson (Grammar of Science, p. 173) clearly explains that with the development of the concept of correlation "the aim of science ceases to be the discovery of "cause" and "effect"; in order to predict future experience it seeks out the phenomena which are most highly correlated." Consider the fluctuation in the number of Dysentery cases. It may be impossible to answer the question : What is the cause of it? "Whereas the question : To what degree are other phenomena associated with it? May admit of easy solution result in invaluable knowledge." From this point of view correlation is simply a convenient description of average experience in the past which is also capable of being used for prediction of average experience in the future.

†The formula is well-known and will be found in every standard text book, e.g. Yule, Text Book of Statistics p. Elderton, Frequency Curves—Brown.

The probable error of a correlation co-efficient is a statistical measure of the unreliability of the co-efficient; the greater the error the greater being the unreliability. It is given by $\pm\ 0{\cdot}6745\ (1-r^2)\ \sqrt{N}$, where r—is the co-efficient of correlation and N is the total number of cases used for finding the correlation. The accuracy depends on the number of observations on which the conclusion is based as well as on the magnitude of the relationship measured. A correlation is not usually considered statistically significant unless its magnitude exceeds twice its probable error.

In Table 6, $r\,(A, H) = + \cdot 4988$. The gross correlation between Appendicitis and Humidity is small and positive and not negligible. Increase in Humidity is associated with a slight increase in the number of cases of Appendicitis. The magnitude of the correlation, 0·4988, is sufficiently large in comparison with its probable error, ±0·0892, to make it definitely significant.

PARTIAL CORRELATIONS :—Now, Appendicitis is also correlated with Rainfall, n(A, R) = +0·6232 while Rainfall is correlated with Humidity, n (H, R) = +0·8419 and the question naturally arises whether the correlation between Appendicitis and Humidity is not merely an indirect one due to their mutual correlation with Rainfall. Evidently it is necessary to determine what will be the correlation between Appendicitis and Humidity when the effect of Rainfall is eliminated. The co-efficient of partial correlation supplies the appropriate solution.*

Partial correlations are written in the following way. r(AH.R) will denote the partial correlation between Appendicitis and Humidity when the effect of Rainfall is eliminated. We see from Table 7 that is—·0056 or practically zero. Proceeding a step further, r(AH.RT) will denote same correlation when the effect of both Rainfall and Temperature is eliminated. Similarly r(AD. RHT) gives the residual correlation between Appendicitis and Dysentery after the elimination of the effect of Rainfall, Humidity and Temperature.

*Standard formulæ for finding the partial correlation are given in Yule.

We have seen that the fluctuations of the same variate may be represented by totally different quantities *e.g.* monthly normals, secular trend, departures from normals or successive differences from month to month. The exact significance of the correlation will naturally depend on the particular quantity used and it is necessary to make a careful discrimination between the different types of correlation.

CORRELATION BETWEEN MONTHLY VALUES.

The crude correlation between the actual monthly values may be a highly misleading thing owing to the composite character of the monthly values themselves. A high correlation between monthly values may arise entirely from the presence of common time factors. Two variates both growing with time may show very high correlation without indicating any organic relationship. For example "no one believes that the correlation between the cancer death-rate and the increasing expenditure on apples per head of population, the value of which is 0·89"—the notorious illustration cited by Karl Pearson—"is a true organic relationship *i.e.* is due to one or more common factors in the two variates. Such high correlations as arise from common growth or decline with time, when interpreted as casual or semi-casual relationships, are in our opinion perfectly idle, and indeed only too apt to be mischievous, and we shall reach nothing, or less than nothing—knighthoods—by the investigation of them" (Biometrika, 1923, Vol. XIV).

It is desirable to be quite clear on this point. A high correlation due to common growth in time is nothing spurious and does not indicate the bankruptcy of statistical methods. It does give a correct and accurate description of average experience in the past, but it fails to furnish any secure basis for the prediction of probable experience in the future. The failure is due to extraneous character of the time factor and not to any inherent defect of the statistical method itself.

High correlation between monthly values may also arise from the presence of synchronous seasonal fluctuations. This point requires a little careful consideration.

CORRELATION BETWEEN THE MONTHLY NORMALS.

Consider the monthly Normals. *If we correlate them we get a measure of the seasonal association irrespective of the individual fluctuations peculiar to particular years.

For example, the correlation between Normal Rainfall and Normal Temperature is r(R, T) = +0·6617. This high positive value is a numerical expression of the familiar fact that the greater part of the Rainfall in Calcutta occurs during the warmer months. The correlation gives an accurate description of average experience in the past and is also fully capable of predicating average experience in the future. We do not feel any hesitation in asserting that in future years Rainfall will continue to be concentrated during the warmer months. Of course the association in this case is so well known that we do not require the correlation co-efficient to make us aware of it; nor do we feel much interest in the prediction since it is so likely to be correct that we accept it as almost inevitable. For Appendicitis and Dysentery (or other specific diseases) such seasonal associations however are not well known and have not become so commonplace and hence deserve attention.

The scope of seasonal correlation is however strictly limited. It can only deal with a stable monthly fluctuations. It cannot tell us whether an abnormally warm month is more likely to be associated with greater rainfall than the average or not. This is due to the very nature of the seasonal correlation which depends on the general average of a large group of factors common to both variates. Particular factors may change from year to year and yet the average ensemblage of a large number of factors will remain fairly stable so that seasonal features are reproduced with great fidelity. This very stability prevents the seasonal fluctuations from taking note of variations due to specific factors which are not common but are peculiar to each variate.

*I shell include for convenience of reference the Averages, either actual or graduated under the general term "Normals."

CORRELATION OF DEPARTURES.

One way of getting rid of the secular trend or the seasonal variations will be to consider the Departures. Correlating them we shall get a better measure of the direct relationship between the two variates.

A Departure correlation can arise from only two sets of terms, (*i*) the presence of common factors which are not affected by the lapse of time and hence may be conveniently called time-less factors and (*ii*) the presence of a few common time factors which are persistent. The latter, if they exist, must be of short period, since all non-periodic factors and terms of long period will get eliminated with the secular trend or get absorbed into the seasonal periodicity.

The question which we are now investigating is precisely this : To what extent do the two variates possess factors in common which are persistent and will render future prediction possible? The time-less factors are obviously of this nature.

But what about the short periodic terms? They may themselves be the product of the common time-less factors and if they are (and there is no a priori reason to assume that they are not) then they will persist and will prove useful in predicting the future sequence. On the other hand if they are entirely extraneous and are unstable then they will have to be eliminated. But whether they are extraneous or not can be found out only by actual experience in each particular case. Hence it seems desirable to leave them in until their extraneous character is proved by actual experience. We thus see that a Departure correlation may be used as a convenient measure of the more direct relationship between two variates (arising from the presence of common factors which are persistent).

When reliable Normals are available Departure correlations can be easily calculated and should always be used. But in actual practice reliable Normals are very often not available and we are inevitably thrown back on some kind or other of graduation which ultimately depends upon the satisfactory fitting of a smooth curve.

The method is one of trial and error and is extremely laborious and as Pearson points out (Biometrika, 1923, Vol. XIV) it is "not a priori possible to select aptly the order requisite for the (smoothing) parabola, nor having selected it to settle, except from the general appearance of the graph, whether it (is) adequate or not or we must go through the great labour of fitting anew a parabola of a still higher order." A good deal naturally depends on the subjective appreciation of the investigator and as exact tests are lacking the whole process is invested with an indeterminate amount of uncertainty and unreliability.

VARIATE DIFFERENCE CORRELATION.

An alternative method of obtaining the correlation between two variates free from secular change has been developed in recent years.

This is the method of Variate Difference Correlation in which successive differences are correlated. Correlating the first differences we get r(dH, dD) which may be written more simply as r (HdD). This measures the connexion between the change in humidity and the change in the number of cases of dysentery. In the case same way we may write

$$r(d^2 H, d^2 D) = r_2 (H,D) - r (d^2 H, d^n D) = r_n (H, D).$$

Theoretical work on the subject (5) has shown that when the difference correlations become stable *i.e.* the correlation between the (n—1)th differences is equal to the correlation between the nth differences then this value gives (under certain conditions, which have been investigated by Pearson and Elderton in the paper already cited) the residual correlation between the variates after elimination of the secular fluctuations.

That is,

$$r (H,D) = r_{n-1} (H,D) = r_n (H,D)$$

This method was severely criticised by G. U. Yule and C. S. Pearsons.

Since then Pearson and Elderton have examined the whole subject exhaustively. (Biometrika 1923 loc. cit.) They have shown (pp. 293) "The process removes the secular trend and correlates the residuals. In these residuals the factors which contribute chiefly to the correlation are the non-periodic and very short periodic terms if the latter exist. If they exist it would indicate that the residuals have a common factor, and that seems to me the very point we set out to enquire into."

The Variate Difference correlations will then form convenient measures of the organic relationship between the Variates. We therefore anticipate a general agreement between these correlations and the Departure correlations. Such agreement will also serve as a useful check on the reliability of either.

The probable error of a difference correlation can be calculated by the formula given by Anderson (Biometrika Vol. X pp. 269—279).

Having obtained the total difference correlations it is a comparatively simple matter to get the corresponding partial difference correlations. We may write the nth difference partial correlation between A and B when R. H and T are kept constant as Rn (A.D.RHT).

RETARDED CORRELATIONS.

In a few special cases I have calculated the correlation between the values of the variates for *different* months *e.g.* correlation of Dysentery in one month with Appendicitis in the second month or with Appendicitis in the third month and so on. In general if Xp is the value of X in the pth month and Yq value of Y in the qth month then the corresponding correlation between the two may be written as r (Xp, Yq). The corresponding nth difference total correlations will be written $r(d^nXp,\ d^nYp)$ or more simply as r_n (Xp, Yq.)

SECTION III. DISCUSSION OF CORRELATIONS.

Before proceeding to discuss the results for Appendicitis and Dysentery it will be useful to consider the correlations for Rainfall, Humidity and Temperature as typical illustrations, which are shown in Table 4.

TABLE 4.

Type	(R, T)	(R, T, H)	(H, T)	(H, T, R)	(R, H)	(R, H, T)
Average	+0·5586	+0·0718	+0·5963	+0·2608	+0·8934	+0·8415
Average Difference	+0·1357	+0·1269	+0·3349	+0·3315	+0·6695	+0·6686
Normal	+0·6617		+0·5625		+0·9022	
Monthly	+0·4410		+0·4907	+0·2464	+0·8519	+0·7999
1st Difference	−0·0449	−0·2077	−0·1549	+0·2634	+0·6805	+0·6966
2nd Difference	−0·3933	−0·3240	−0·2357	−0·0061	+0·5879	+0·5542
3rd ,,	−0·4672	−0·3434	−0·3494	−0·0967	+0·6016	+0·5292
4th ,,	−0·4937	−0·3224	−0·4133	−0·1325	+0·6624	+0·5790
5th ,,	−0·5143	−0·3089	−0·4522	−0·1470	+0·7057	+0·6185
Departures from Normals	−0·4168	−0·2608	−0·3977	−0·2099	+0·5470	+0·4571
From Averages	−0·5862	−0·3735	−0·5691	−0·3371	+0·5973	+0·3959

RAINFALL AND TEMPERATURE.

The crude averages show a high seasonal association of +0·56. The true normal correlation is higher still, +0·44. But on differencing the correlations are immediately reduced and change their sign and ultimately at the 5th step the difference correlation takes up the value—0·51. This shows that although the greater part of the annual rainfall in Calcutta occurs during the warmer months, a bigger rainfall than the average will keep the temperature distinctly cooler than usual.

The correlation of departures from the normals is −0·42 which definitely supports the difference correlation.

HUMIDITY AND TEMPERATURE.

The average correlation is 0·60; the normal correlation is also just about the same. The monthly correlation is also fairly 0·49. On differencing the correlation again reverses its sign and becomes −0·45. On eliminating the effect of Rainfall and the co-efficient is reduced to −0·15. The departure correlations are total 0·40 and partial −0·21 and both support the difference correlations. Thus here also in spite of the well marked seasonal association the more direct relationship is negative showing that abnormally high temperatures are associated with unusual dryness of the air.

RAINFALL AND HUMIDITY.

The seasonal association is very high, the co-efficient being for both averages and normals just about +0·90. The monthly correlation is +0·85. On differencing the value is reduced but remains substantially high and positive the total correlation at the 5th difference being +0·71. There is very little reduction on the elimination of the effect of temperature, the 5th difference partial being +0·62. The departure correlations are +0·55 and +0·46 respectively. All this shows that not only is there a strong seasonal
fairly close connection between the variation of the two elements in
association between Rainfall and Humidity but there also exists a

APPENDICITIS AND RAINFALL.

TABLE 5.

	(A, R)	(A, R, T)	(A, R, H)	(A, R, H, T)
1. Crude Averages	+0·7881	+ ·8081	+ ·4293	+ ·4865
2. Crude Average Differences	+ ·7243	+ ·7548	+ ·5121	+ ·5192
3. 7-point Averages of Appendicitis and Normal Rainfall.	+ ·8938			
4. Monthly values	+ ·6232	+ ·6291	+ ·4818	+ ·4469
5. 1st Differences	+ ·4320	+ ·4307	+ ·3649	+ ·3551
6. 2nd Differences	+ ·4284	+ ·4048	+ ·3979	+ ·3839
7. 3rd Differences	+ ·4544	+ ·4510	+ ·4258	+ ·4360
8. 4th Differences	+ ·4649	+ ·4798	+ ·4412	+ ·4615
9. 5th Differences	+ ·4692	+ ·4885	+ ·4596	+ ·4513
Departures from				
10. Crude Averages	+ ·2815	+ ·1832	+ ·4034	+ ·3183
11. 15-point Smooth and Normal	+ ·3629	+ ·3365	+ ·2319	+ ·3745
12. 7-point Average and Normal	+ ·2621	+ ·1772	+ ·3669	+ ·3113
13. 2-term Harmonic	+ ·3548	+ ·3056	+ ·4072	+ ·3745

RETARDED CORRELATIONS.

(R_1, A_2)	=	+	·3194
$(D^3 R_1, D^1 A_2$	=	−	·2358
$(R_1, A_2 \cdot A_1)$	=	+	·3256
$(R_1 A_2 \cdot R_2)$	=	−	·0376
$(R_1 A_2 \cdot A_1 R_2)$	=	+	·0708
$(A_1 A_2)$	=	+	·1039
$(A_1 A_2 R_1)$	=	−	·1804
$(R_1 R_2)$	=	+	·5518
$(D^1 R_1, D^1 R_2)$	=	−	·7214
(R_1, A_3)	=	+	·0700
(R_1, A_1)	=	+	·0251
(R_1, A_1, R_2)	=	+	·5378
$(R_2, A_2 \cdot A_1)$	=	+	·6368

individual months, so that exceptionally bigger Rainfall is likely to be accompanied by abnormal dampness of the air and *vice versa*.

We see that in all the above examples there is fair agreement between the difference and the normal departure correlations. The numerical values are not exactly the same but neither are they widely different. Assuming that the departure correlations (based on normals obtained from about 30 years data) give 'true' values, the "errors" of the Difference correlations are $-0·09$ and $-0·05$, $-0·05$ and $-0·05$, $+0·16$ and $+0·15$ in the above three examples. That is difference correlations give errors of roughly from 10% to 30%. Considering that the total number of months is only 34, such results are not unsatisfactory. We shall therefore feel justified in using difference correlations (when they are stable) as fair approximations to the true organic correlations.

In the next section I shall consider in detail the actual correlation between the different variates.

RAINFALL AND APPENDICITIS—(Table 5).

The crude averages give a correlation of $+0·79$, showing high seasonal association between rainfall and appendicitis. The 7 point graduated averages of appendicitis and normal rainfall show a still higher correlation ($+0·89$). The elimination of the effect of temperature and humidity reduces the correlation to some extent; it yet remains fairly high $+0·49$ for the averages. The average difference (that is the change of average from month to month) also gives high correlation (0·72), the partial in this case being also proportionally high (0·52). There can scarcely be any doubt that the incidence of appendicitis is much greater than usual during the rainy season.

The monthly correlation is also high, 0·62. Taking differences it is reduced but remains substantially high and is very stable, its value at the 5th difference being 0·47. The elimination of temperature and humidity has practically no effect; in fact the second order partial is 0·48. The difference correlations show no sign of decrease and agree remarkably well among themselves.

The departures give a correlation varying from 0·26 to 0·36 for the total, and from 0·31 to 0·37 for partial (after eliminating humidity and temperature). All the departure correlations agree fairly well among themselves and generally support the difference correlations. We therefore feel justified in concluding that not only is appendicitis more prevalent during the rainy season but its incidence is actually aggavated by an excess of rainfall. So that a bigger rainfall than usual in any month is accompanied by an increase in the number of cases of appendicitis.

I have calculated several retarded correlations which bring out certain interesting points. Thus the gross effect of rainfall rapidly decreases with time. The correlation between R_1 (rainfall in the first month) with A (appendicitis in the second month) is 0·32; with A_3 (appendicitis in the third month) it is 0·07 and it practically vanishes in the fourth month. But the third difference correlation for even the first succeeding month is actually negative (−0·24). This shows that apart from seasonal influence rainfall has no aggravating effect in the second month.

The gross correlation between A_1 and A_2 (appendicitis in two succeeding months) is small, 0·10. Even this small positive correlation arises indirectly through the presence of a comparatively high seasonal correlation between rainfall in two succeeding months (0·55)*. The actual correlation between A_1 and A_2 (appendicitis in two succeeding months) when rainfall in the second month is kept constant is negative (−0·18), which shows that, apart from the influence of rainfall, an excess of appendicitis in one month is likely to be followed by a slight decline in the succeeding month. This is also corroborated by the previously noticed negative correlation of −0·24 between the third difference. The same thing is also indicated by the fact that correlation of R_1 (rainfall in the first month) and A_2 (appendicitis in the second month) as well as that between R_2 (rainfall in the second month) and A_2 (appendicitis in the second month) are both slightly increased by keeping A_1 (appendi-

*It is interesting to note that this correlation itself is entirely seasonal; the third difference gives a high negative correlation of —0.72 showing that an abnormally wet month is very likely to be followed by an abnormally dry one.

APPENDICITIS AND HUMIDITY.

TABLE 6.

	(A, H)	(R, H, T)	(A, H, R)	(A, H, R, T)
1. Crude Average	+0·7360	+ ·7559	+ ·1154	+ ·2384
2. Average Difference	+ ·6503	+ ·7422	+ ·3231	+ ·4867
3. 7-point Smooth and Normal	+ ·8552			
4. Monthly values	+ ·4988	+ ·4952	− ·0056	+ ·0412
5. 1st Difference	+ ·2549	+ ·2659	− ·0592	− ·0527
6. 2nd Difference	+ ·1914	+ ·1615	− ·0828	− ·0827
7. 3rd Difference	+ ·2044	+ ·1726	− ·0970	− ·0873
8. 4th Difference	+ ·2145	+ ·1907	− ·1480	− ·1214
9. 5th Difference	+ ·2141	+ ·1893	− ·1870	− ·1646
"Departures" from				
10. Crude Averages	− ·0692	− ·2532	− ·3084	− ·3608
11. 7-point Averages and Normal	− ·0804	− ·2051	− ·2770	− ·3269
12. 2-term Harmonic and Normal	+ ·0257	− ·0589	− ·2152	− ·2347

RETARDED CORRELATIONS.

$(H_1 A_2 = + \cdot 3539$

$(D^3 H_1, D_3 A_3) = - \cdot 1667$

$(H_1 A_2 \cdot A_1) = + \cdot 3487$

$(D^1 A_2 \cdot H_2 = - \cdot 0407$

$(H_1 A_2 \cdot H_2 A^1) = - \cdot 0026$

$(H_1 H_2) = + \cdot 5210$

$(D^3 H_1, D^3 H_2) = + \cdot 5736$

$(A_1 A_2 \cdot H_1 = + \cdot 1118$

$(A_1 A_2 \cdot H_1 H_2 = + \cdot 1042$

$(H_1 A_3) = + \cdot 1366$

$(H_1 A_4) = - \cdot 1433$

citis in the first month) constant. We conclude therefore that although rainfall definitely acts as an aggravating influence on appendicitis in the same month its effect is not directly carried over to the succeeding month. In other words the harmful effect of rainfall is practically confined to the month of its occurrence.

APPENDICITIS AND HUMIDITY—(Table 6).

Both the crude averages as well as the graduated averages and normals show high seasonal association 0·74 and 0·86 respectively. The elimination of the temperature effect makes no difference showing that temperature exerts very little influence. The elimination of rainfall however affects the correlation very considerably, reducing it to 0·11 for averages and for normals showing that the greater part of the seasonal association between appendicitis and humidity arises indirectly through mutual correlation with rainfall. The monthly correlation is 0·50, which becomes practically zero on the elimination of rainfall. On taking differences also the correlation is reduced, the total correlation becoming fairly steady at 0·21. Elimination of the temperature effect again makes no difference while the elimination of rainfall immediately changes the sign of the partial correlation which then remains steadily negative. At the 5th difference the value of the second order partial is −0·16, but it has not become steady and is apparently still growing numerically.

Departures give a total correlation varying from 0·02 to −0·08; eliminating rainfall and temperature the correlation varies from −0·23 to −0·36. Taken in conjunction with the fact that the difference correlations are still growing numerically it seems probable that there exists a residual correlation of the order of −0·25. We conclude therefore that abnormal dryness of the air exerts a slight aggravating influence on the incidence of appendicitis.

The retarded correlation between H_1 (humidity in the first month) and A_2 (appendicitis in the second month) is 0·35. It is reduced to 0·14 for A_3 (appendicitis in the third month) and actually becomes negative (−0·14) with A_4 (appendicitis in the fourth month). Even the positive correlation of 0·35 for two suc-

APPENDICITIS AND TEMPERATURE.

TABLE 7.

	(A, T)	(A, T, R)	(A, T, H)	(A, T, R, H)
1. Crude Averages	+0·2486	− ·3753	− ·3501	− ·4229
2. Average Difference	− ·1285	− ·3320	− ·4839	− ·4917
3. 7-point Average and Normal	+ ·3876			
4. Monthly values	+ ·1468	− ·1823	− ·1298	− ·1867
5. 1st Difference	− 0486	− ·0324	− ·0922	− ·0180
6. 2nd Difference	− ·1540	+ ·0175	− ·1142	+ ·0169
7. 3rd Difference	− ·1260	+ ·1096	− ·0595	+ ·1011
8. 4th Difference	− ·1008	+ ·1672	− ·0136	+ ·1514
9. 5th Difference	− ·1020	+ ·1839	− ·0060	+ ·1610
"Departures" from				
10. Crude Averages	− ·2340	− ·0888	− ·3333	− ·2151
11. 7-point Average and Normal	− ·2553	− ·1666	− ·3141	− ·3142
12. 2-term Harmonics	− ·1980	− ·0590	− ·2047	− ·1123

ceeding months is due to the high seasonal association between humidity of the two succeeding months (0·52). The third difference correlation is actually negative, $-\cdot 17$. Further if we keep H (humidity in the second month) constant then the correlation between H_1 and A_2 (humidity in the first month and appendicitis in the second month) becomes $-0\cdot 04$. If in addition we keep A_1 (appendicitis in the first month) constant then the correlation is practically nil.

It is interesting to note that the correlation between A_1 and A_2 (that is, between appendicitis in two succeeding effects of humidity). It confirms the slight negative correlation already obtained after the elimination of rainfall.

The general conclusion is that although high seasonal (positive) association is found to exist between appendicitis and humidity it is almost entirely due to mutual correlations with rainfall.

In fact the more direct relationship is probably negative so that an abnormal temperature of the air exerts an aggravating influence on the incidence of the disease. This influence however is not persistent and practically vanishes in the second month.

APPENDICITIS AND TEMPERATURE—(Table 7).

The seasonal association is small, correlation between averages being 0·25 and between normals 0·39. It becomes negative on the elimination of rainfall and humidity. The average difference correlation is also negative.

The monthly correlation is small and positive (0·15) which on differencing changes sign and practically becomes steady at $-0\cdot 10$.

The departures give consistently small negative values varying between $-\cdot 19$ and $-\cdot 25$ for the total and $-1\cdot 1$ and $-\cdot 31$ for the partial. The elimination of rainfall however gives small positive correlations in the case of the differences. This is rather puzzling but I believe merely a fresh indication of the dominating character of the rainfall, which is so much of a controlling factor that its elimination leaves the situation extremely uncertain,

DYSENTERY AND RAINFALL—(Table 8).

The seasonal correlation is negative but small which merely confirms the winter character of the disease. The monthly correlation is −0·30 which becomes substantially reduced by the elimination of temperature but remains practically unaffected by the elimination of humidity. On differencing the co-efficients change sign and remain systematically positive. The numerical values however fluctuate rather unsteadily.

The departure correlations are all negative and small; the partials however are again unsteady. The evidence in this case is therefore distinctly uncertain and the only thing we can do is to confess our ignorance and say that on the basis of the present analysis we cannot reach any significant conclusions about the relationship between Rainfall and Dysentery.

DYSENTERY AND HUMIDITY—(Table 9).

The seasonal correlation is small and negative, −0·17. The monthly correlation also is small and negative and has an almost identical value −0·17.

On differencing the numerical value is still further reduced and the total correlations become fairly steady at −·07. Even on eliminating rainfall and humidity the difference correlations remain small and negative. At the 5th difference its value is −0·18 but is apparently still decreasing.

The departure correlations also are all small and vary between −·06 and −·17 for the total and between −·09 and +·09 for the partial. A slight negative correlation may exist; but if it does exist it must be extremely small in magnitude.

DYSENTERY AND TEMPERATURE—(Table 10).

The seasonal association is negative and is fairly high (−0·69) for average indicating that dysentery is distinctly more prevalent in autumn and winter. The monthly correlation, −0·47 is also negative and fairly large. The elimination of humidity has no

DYSENTERY AND RAINFALL.

TABLE 8.

	(D R)	(D R, T)	(D R, H)	(D R, T H)
1. Crude Averages	− ·3555	+ ·0541	− ·4579	− ·6151
2. Average Difference	− ·2049	− ·1775	− ·3125	− ·3676
4. Monthly values	− ·3080	− ·1268	− ·3245	− ·3215
5. 1st Difference	− ·1129	− ·1092	+ ·0139	+ ·0416
6. 2nd Difference	+ ·2286	+ ·2965	+ ·4227	+ ·4711
7. 3rd Difference	+ ·1212	+ ·2338	+ ·2362	+ ·3089
8. 4th Difference	+ ·1481	+ ·3035	+ ·2580	+ ·3532
9. 5th Difference	+ ·1225	+ ·3020	+ ·2425	+ ·3451
"Departures" from				
10. Crude Averages	− ·2113	− ·0581	− ·1795	− ·0891
11. 15-point Average and Normal	− ·1876	− ·1632	− ·1393	− ·1316
12. Secular graduation and Normal	− ·1184	− ·0277	− ·1837	+ ·0168
13. 2-term Harmonic and Normal	− ·1870	− ·0973	− ·1837	− ·1299

DYSENTERY AND HUMIDITY.

TABLE 9.

	(D H)	(D H, T)	(D H, R)	(D H, R T)
1. Crude Averages	− ·1710			
2. Average Difference	+ ·0405			
4. Monthly values	− ·1680	+ ·0819	+ ·1778	+ ·3078
5. 1st Difference	− ·1806	− ·1987	− ·1426	− ·1721
6. 2nd Differene	− ·1829	− ·1630	− ·4029	− ·4118
7. 3rd Difference	− ·1102	− ·0528	− ·2309	− ·2159
8. 4th Difference	− ·0675	+ ·0270	− ·2235	− ·1912
9. 5th Difference	− ·0693	+ ·0504	− ·2214	− ·1820
"Departures" from				
10. Crude Averages	− ·1143	+ ·0597	+ ·0152	+ ·0902
11. 15-point Average and Normal	− ·1317	− ·1025	− ·0354	− ·0318
12. Secular graduation and Normal	− ·1184	− ·0277	− ·0288	+ ·0168
13. 2-term Harmonic	− ·0613	+ ·0397	+ ·0499	+ ·0951

DYSENTERY AND TEMPERATURE.

TABLE 10.

	(D T)	(D T, R)	(D T, H)	(D T, R H)
1. Crude Average	− ·6945	− ·6396	− ·7491	− ·8077
2. Average Difference	− ·2578	− ·2371	− ·2883	− ·3482
4. Monthly values	− ·4707	− ·3922	− ·4522	− ·4571
5. 1st Difference	+ ·0958	+ ·0914	+ ·1274	+ ·1332
6. 2nd Difference	+ ·1079	+ ·2210	+ ·0678	+ ·2388
7. 3rd Difference	+ ·1761	+ ·2652	+ ·1478	+ ·2508
8. 4th Difference	+ ·2214	+ ·3424	+ ·2130	+ ·3239
9. 5th Difference	+ ·2494	+ ·3670	+ ·2451	+ ·3467
"Departures" from				
10. 15-point Smooth and Normal	+ ·1950	+ ·3884	+ ·3218	+ ·4140
11. Crude Averages	+ ·2836	+ ·2017	+ ·2676	+ ·2118
12. 15-point Average and Normal	+ ·0957	+ ·0196	+ ·0476	+ ·0120
13. Secular graduation and Normal	+ ·2254	+ ·1952	+ ·1732	+ ·1717
14. 2-term Harmonic and Normal	+ ·2429	+ ·1848	+ ·2386	+ ·2011

appreciable effect. The elimination of rainfall is slightly more effective but not very much so.

On differencing, the results are completely reversed. The correlations all become positive. The 5th total difference correlation is 0·25 which is positive and not negligible. The partial is even higher and is 0·35. Further they have not yet become stable and are still growing.

The departures give consistently positive correlations which agree fairly well among themselves with the only exception of the departures from the 15 point average. The partials also, with the same exception, show fair agreement and give moderate positive values.

Taking everything into consideration it seems clear that although dysentery is more prevalent during winter its incidence is perceptibly aggravated by abnormally high temperatures.

APPENDICITIS AND DYSENTERY—(Table 11).

Finally I must consider the relationship between Appendicitis and Dysentery. I have examined 24 seasonal, 1 monthly, 48 difference, 40 departure and about 16 deferred correlations. They are all small and almost all negative. The difference and departure correlations are in good agreement. The total correlations vary from −·12 to −·31, the average value of 12 correlations being −0·18. The effect of eliminating rainfall, humidity and temperature is slight; the partial varying from −0·15 to −0·37 with an average value of −0·20.

The deferred correlations also are mostly negative. The highest positive correlation is 0·44 between dysentery in one month with appendicitis in the 9th succeeding month. But even here the first difference correlation is only 0·09 and the second difference correlation is −0·14 which is again negative and just about the old value. Thus I completely fail to trace any positive relationship between Dysentery and Appendicitis, either immediate or deferred. Whatever method I adopt I ultimately reach a small negative correlation.

APPENDICITIS AND DYSENTRY.

TABLE 11.

	A.D	A D. R	A D. H	A D. T	A D, R H	A D, R T	A D, H T	A D, R H T
1. Crude Averages	−·1466	+·2332	−·0376	+·0376	+·2063	−·0096	−·4729	−·2532
2 Average Difference	+·1114	+·0548	−·1814	−·1508	−·0262	−·0261	− 3830	−·2418
3. 15-point Smooth and 15-point Smooth	−·2041	−·0		−·2364				
4. Monthly values	−·2154	−·0317	−·1541	−·1677	−·0312	−·1141	−·2406	−·1144
5. 1st Difference	−·1435	−·1057	−·1025	−·1396	−·1155	−·1032	−·0919	−·1142
6. 2nd Difference	−·1332	−·2627	−·1018	−·1187	−·3248	−·2734	−·0949	−·3387
7. 3rd Difference	−·1181	−·1959	−·0983	−·0982	−·2254	−·2348	−·0907	−·2604
8. 4th Difference	−·1273	−·2240	−·1158	−·1082	−·2648	−·3035	−·1156	−·3353
9. 5th Difference	−·1485	−·2350	−·1372	−·1278	−·2886	−·3307	−·1400	−·3720
"Departures" from								
10. Crude Averages	−·2783	−·2333	−·2891	−·2273	−·2407	−·2208	−·2201	−·2030
11. 7-pt. Average of App. & 15-pt. Average of App.	−·1731	−·1307	−·1859	−·1545	−·1463	−·1292	−·1802	−·1479
12. 7-pt. Average of App. & Secular grad. of D.	−·1802	−·1557	−·1977	−·1303	−·2012	−·1274	−·1533	
13. 2-term Harmonics	−·3061	−·2611	−·3052	−·2711	−·2566	−·2550	−·2697	−·2404

RETARDED CORRELATIONS.

$(D_1 A_2) = -\ {\cdot}3990$
$(D_1 A_3) = -\ {\cdot}3219$
$(D_1 A_4) - -\ {\cdot}3857$
$(D_1 A_5) = -\ {\cdot}3637$
$(D_1 A_6) = -\ {\cdot}2081$
$(D_1 A_7) = -\ {\cdot}0803$
$(D_1 A_8) = +\ {\cdot}1773$
$(D_1 A_9) = +\ {\cdot}3926$
$(D_1 A_{10}) = +\ {\cdot}4439$
$(D_1 A_{11}) = +\ {\cdot}3969$
$(D_1 A_{12}) = +\ {\cdot}0025$

The general concordance gives me confidence in inferring that there exists a real but small negative correlation between the two variates showing a slight compensatory effect so that an increase in the incidence of dysentery in one month is accompanied by a slight decrease in the incidence of appendicitis in the same month.

NOTE ON THE SEASONAL CORRELATION.

We have already seen that the average correlations show a greater prevalence of Appendicitis during the rainy season and of Dysentery during autumn and winter. The same conclusions could have been deduced more simply from a study of the monthly averages themselves. Diagram 1 clearly shows that a greater number of cases of appendicitis occurs during July—September and of Dysentery during October—February. But one great advantage of the method of correlation is that it supplies the same information in a numerical form which renders quantitative comparisons possible. The correlational method also makes it possible to eliminate the effect of particular factors by taking partial co-efficients. For example in the case of appendicitis we saw that in spite of its high seasonal association with Humidity, the latter factor is really of little importance. We could not of course obtain this information by any amount of study of the monthly averages or their graphs.

At the same time it seems desirable to point out the limitations of the average correlations. For example it is perfectly useless to try to draw any conclusions from "retarded" values. Consider Table 12.

In Col. 1, −0·17, gives the correlation of Average Rainfall with Average Humidity in the same month. The figure in the second row, −0·28, gives the correlation of Average Humidity in one month with the Average Rainfall in the next month and so on until the figure in the last row, −0·64, gives the correlation of the Average Humidity in one month with the Average Rainfall in the 12th month.

Certain features are prominent in the above table. In every column there is a regular gradation in the numerical values and

TABLE 12 RETARDED AVERAGE CORRELATIONS.

Humidity. & Dysentery.	Temperature. & Dysentery.	Rainfall. & Dysentery.	Humidity. & Appendicitis.	Temperature. & Appendicitis.	Rainfall. & Appendicitis.	Dysentery. & Appendicitis.	
−0·1710	−0·6945	−0·3555	0·7360	0·2486	0·7888	0·1466	Same month.
0·2834	−0·3681	0·1154	0·5225	0·5929	0·3923	0·4104	1st succeeding month.
0·7061	0·0381	0·5545	0·3656	0·7209	0·2484	0·6401	2nd ..
0·9360	0·4351	0·7794	0·0285	0·6840	0·1422	0·5470	3rd ..
0·8663	0·7630	0·8348	0·3309	0·2272	0·1168	0·6329	4th ..
0·5802	0·8921	0·6155	0·4612	0·2569	0·1891	0·1989	5th ..
0·2008	0·7639	0·2666	0·6985	0·6166	0·5644	0·0009	6th ..
0·2826	0·4109	0·0331	0·6542	0·6603	0·6960	0·4111	7th ..
0·7232	0·0610	0·5177	0·4066	0·4944	0·6396	0·7159	8th ..
0·8694	0·5275	0·7158	0·0623	0·3140	0·2317	0·6579	9th ..
0·8433	0·8035	0·8263	0·3424	0·1592	0·3481	0·5683	10th ..
0·6426	0·8695	0·7178	0·6283	0·0007	0·5182	0·2078	11th ..

positive and negative correlations occur in equal numbers ; also high numerical values are usually separated by a six months interval The explanation is simple but instructive.

Consider two variates having the same annual period. Assume that the periodicity of each is of the simplest type, then they can be represented by simple sine curves. (see figure 1). Now if the crests of the two curves coincide (*i.e.* the two variates are in the same phase) the correlation will obviously be 1. Retard one curve on the other, they will then go out of step and the correlation will steadily diminish until when the crest of one curve lies midway between the crest and trough of the other the correlation becomes zero. With further shift the correlation will become negative but its numerical value will steadily increase until it attains the value −1, when the crest of one lies on the trough of the other. The correlation will then decrease become zero and then again increase to 1. It is also obvious that 6 positive and 6 negative values will be attained during one complete cycle.

In any actual concrete example the periodicities will not be of a such strictly simple character as assumed above. But whenever a dominant term of approximately the same period is present in both the variates the sequence described above will be reproduced with more or less accuracy. Table 12 is a good illustration.

We thus see that high values of retarded correlations are merely the product of the common dominant periodicity. We cannot legitimately draw any conclusion from such correlations and it is useless to consider them.

SUMMARY OF CONCLUSIONS.

In investigating the influence of weather factors on the incidence of specific diseases the method of correlation possesses great advantages. It gives information in a precise quantitative form, to a very large extent free from "personal" bias, which renders accurate comparisons possible. By the method of partial correlation it supplies information which could not be otherwise obtained.

Correlation of monthly averages gives valuable information about seasonal peculiarities but is limited in scope. Deferred relations between monthly averages are perfectly useless.

In the case of material showing common growth in time or showing seasonal periodicity monthly correlations are also practically useless and are apt to be highly misleading. The only proper way to investigate the more direct connection between variates is to correlate the departures from the monthly normals (or the secular trend). Where reliable normals are not available some indirect method will have to be adopted. The method of Variate Difference correlation offers certain advantages. It is straightforward and easy of application and is to some extent under control. In the present example the dominant periodicity is an annual one. Working with 5th differences the variate difference method gave fairly satisfactory results probably within 30% of the true departure correlations. The difference correlations were however usually numerically greater showing that all traces of "periodic" association had not been eliminated.

Correlation of departures from suitable graduations may be used as a check. The method is one of trial and error and it is doubtful whether the results obtained are always commensurate with the great amount of labour involved.

Finally I wish to emphasise that Results based on the cursory examination of a few graphs are not merely out of date but are positively mischievous and must be eliminated from scientific enquiries as early as possible.

The following conclusions are based on the experience of two Calcutta Hospitals during the period March, 1920 to December, 1922.

Appendicitis.—Appendicitis is distinctly more prevalent during the rainy season. Its incidence is actually aggravated by an excess of Rainfall so that a bigger rainfall than usual in any month is usually accompanied by an increase in the number of cases of Appendicitis. This harmful influence of Rainfall is however practically confined to the month of its occurrence.

An abnormal dryness of the air (low Humidity) also exerts a slight aggravating influence. The effect however is small and is not persistent; it practically vanishes in the first succeeding month.

It also seems possible that although Appendicitis is not a winter disease its incidence is aggravated by abnormally cool weather. Owing to the dominating influence of Rainfall the evidence is not quite clear and the effect if real is not large.

There also seems to exist a slight compensatory relation between Appendicitis during two succeeding months so that an increase in Appendicitis in one month is likely to be followed by a slight decrease in the succeeding month.

Dysentery.—Dysentery is more prevalent during autumn and winter. The effect of Rainfall is not clear and we cannot draw any definite conclusions. The influence of Humidity, if any exists, must be very small in magnitude. On the other hand there are clear indications to show that in spite of the winter character of the disease, abnormally warm weather exerts a distinctly aggravating influence on its incidence.

Appendicitis and Dysentery.—There is no trace of a positive correlation between Dysentery and Appendicitis either immediate or deferred. On the other hand all evidence point to the existence of a slight compensatory relationship, so that an increase in the incidence of Dysentery in one month is likely to be accompanied by a slight decrease in the incidence of Appendicitis in the same month and *vice versa*.

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(*N.B.*—For Discussion refer to page 211.

Review.

Aids to case taking.

A practical guide to the examination and recording of medical cases—By Henry Lawrence McKisack, M.D., F.R.C.P. (Lond.), London : Bailliere, Tindall and Cox. 1926 Pp. 168. 4/6d. nett.

This useful little book is one of the famous aids series. It contains all that a clinical clerk ought to know to prepare his case note. Though a student of tropical diseases may not find sufficient reference to that branch of medicine, still he will never be wide of the mark in the difficult art of diagnosis. The chief feature of the book is the method which prevents altogether loose thinking. As a matter of fact it clinches the diagnosis. The get-up of the book is excellent.

N. C. M.

Medical News.

Dr. R. B. Khambata, Assistant Director of Public Health, is temporarily appointed to act as Professor of Hygiene, School of Tropical Medicine and Hygiene, with effect from the forenoon of the 1st November, 1926, until further orders.

In exercise of the power conferred by clause (b) of section 4 of the Bengal Medical Act 1914 (Bengal Act VI of 1914), the Governor in Council is pleased to appoint Lieutenant-Colonel F. A. F. Barnardo, C.I.E., C.B.E., M.D., F.R.C.P., F.R.C.S., I.M.S., to be a member of the Bengal Council of Medical Registration, vice Lieutenant-Colonel J. C. H. Leicester, M.D., F.R.C.P., F.R.C.S., V.H.S., I.M.S., appointed to be President.

In exercise of the power conferred by article 3 of the statutes of the State Medical Faculty of Bengal, the Governor in Council is pleased to appoint Lieutenant-Colonel F. A. F. Barnardo, C.I.E., C.B.E., M.D., F.R.C.P., F.R.C.S., I.M.S., to be a member of the Governing body of the said Faculty, vice Lieutenant-Colonel J. C. H. Leicester, M.D., F.R.C.P., F.R.C.S., V.H.S., I.M.S., appointed to be President.