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Bacteria of the Alimentary Canal,

ESPECIALLY IN THE

Diarrhœas of Infancy.

BY

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THE BACTERIA OF THE ALIMENTARY CANAL ESPECIALLY IN THE DIARRHŒAS OF INFANCY.

BY JOHN A. JEFFRIES, M.D.

THAT the interest lately developed in the study of the relation of bacteria to the diarrhœal diseases of infancy is justified will probably be acknowledged by all. On the other hand, owing to the recent development of bacteriology and the obscure way in which some of the most important articles have been published, those not actively studying the subject have but slight ideas of the advance made, advance already giving results in practice.

Both treatment and prophylaxis have improved. An infant can now cross the ocean provided with a supply of milk, cream mixture, or the like, sure to keep fresh, and identical with the food of the nursery. We are now justified in looking forward to another stride in the difficult subjects of artificial feeding of infants and the intestinal troubles of the same. The last great step was made by the chemical study of foods and the general realization of the fact that cows' milk is not mothers' milk, and a growing belief that were young animals fitted to feed on vegetable food nature would not have taxed the parents so heavily to provide an animal food. All the higher forms of life conform to this law, the helpless young are fed on animal food. We see this not only in the milk of

mammals, but in the insect food of the helpless young of birds.

Bacteriology has now shown that, provided we start with a food chemically right, care must be taken or our worst foes, bacteria, will quickly invade the field, and, as if by the wave of a wicked fairy's wand, change the whole into poisons. Not only do bacteria work harm from without and within the body, but certain forms appear positively beneficial, inasmuch as by pre-emption of the alimentary canal they exclude more noxious forms.

The cavity of the mouth and throat offer little of importance to the subject. Many forms of bacteria are known to occur and to play a causative part in certain local diseases, as decaying teeth, thrush, and the like. Again, forms pathogenic to animals commonly occur, and forms known to be so to man are by no means rare. Yet on the whole the flora of the mouth is fairly constant, as shown by Vignal,[1] and Miller,[2] and chiefly of interest not for the harm it does, but for the converse. How is it that so many noxious forms existing in the mouth and being swallowed with the food and saliva disease is not vastly more rife? This is an interesting question. Unfortunately, as yet replies can only be made in general terms, that the epithelium of the mouth, true skin, is thick and the parts beneath very vascular, thus offering decided mechanical difficulties to the entrance of bacteria, and a prompt, powerful response from the system to any threatened invasion.

Once arrived in the stomach it has, until recently, been generally held that the bacteria would be killed by the hydrochloric acid, perhaps digested by the

[1] Vignal. Archiv. de Physiologie, 1886, p. 325.
[2] Miller. Deutsch. Med. Wochenschr., 1884, p. 781, 1885, p. 843; 1886, p. 117.

pepsin. Like other mistaken beliefs it is difficult to trace this to its source, or to collect and arrange the arguments in its favor.

Bienstock [3] seems to have been the first to put this idea forward, supported by experiments. This author held that only four or five kinds of bacteria occurred in the intestines, and on experimenting with those in a spore-free condition found them to be killed by a 2 % hydrochloric acid solution.

Koch first showed that the vegetative form of the anthrax bacillus was unable to resist the action of the hydrochloric acid during the normal course of digestion of vegetable eaters, but that the spores could pass through.

Koch, however, also pointed out in relation to the cholera bacillus that the empty stomach is not acid, that all the food does not stay there for hours, and that time is required to bring the hydrochloric acid up to the normal, 2 %.

We now know, thanks to the studies of Miller, De Barry and Escherich, that living bacteria are to be found in the stomachs of man and the animals, while the literature on sarcina ventriculi, a special form, beginning with the note by Goodsir [4] in 1842, has grown to large proportions in the work of Falkenheim [5] and others.

Miller [2] has isolated several forms from the digestive tract, and studied the effect of artificial digestion on pure cultures, but disregarded the question of spores. This was unfortunate, as it has always been granted that spores could pass through the stomach, yet it is improbable that spores existed in all his cultures, such

[3] Bienstock. Fortschr. d. Medecin, 1883, p. 609 ; Zeitschr. f. Klin. Med., 1884, p. 1.
[4] Goodsir. Edinborough Medical and Surgical Journal, 1842.
[5] Falkenheim. Archiv. f. Experim. Pathol. u. Pharmakol., 1885, Vol. XIX, p. 339.

not usually being formed under the conditions with which they were grown. He showed that the full period of digestion with a .16% hydrochloric acid solution was required to affect the forms studied. Also, Miller found that, contrary to the statements of Bienstock, eight forms found in the mouth occur in the stomach, and twelve in the stools. His final conclusions are that all the forms studied could pass through the stomach during the first part of digestion. Here it is of importance to remember that the food begins to pass through the pylorus in from fifteen to twenty minutes after eating.

In a later article Miller returned to the subject and showed that four kinds of gas-producing forms isolated by himself from the stomach of a man, were able to pass through the stomach of a dog. Miller mixed pure cultures with the food and fed four dogs, later killing them two and a-half, six, eight and nine hours after feeding. In the first two the stomach and intestines were found acid, in the third the lower part was alkaline, and in the fourth the entire digestive tract. All four kinds were again isolated from the stomachs, small intestines and rectums of the first three dogs. No living bacteria were found in the stomach of the fourth dog. The dogs suffered from diarrhœa. Lastly Miller took a milk culture of his first species and suffered sufficiently to forego all further experiments on himself.

This last set of experiments shows clearly that bacteria can pass through the stomach into the intestines and live for a considerable time, but is open to the same objection as his first set, the failure to exclude spores.

De Barry[6] studied the vomitus ejected by a man, and

[6] De Barry. Archiv. f. Experimen. Pathol. u. Pharmachol., 1886, Vol. XX, pp. 24 and 270.

found seven species besides the mycelium of a mould. His work, however, was not done in strict accord with modern methods.

The most recent and conclusive work has been done by Macfadyen,[7] to whose very able article all students of the subject are much indebted. He experimented with pure cultures of harmless and pathogenic forms exposed to the action of pepsin, hydrochloric acid, and the two together in various strengths. As results he found that pepsin had no effect, while it required the action of a .05% to a .3% solution of hydrochloric acid for four hours at 37° centigrade to kill the various species used. The comma, Finkler-Prior and bacillus prodigiosus were killed by the .05% solution, while .3%, fifty per cent. more than the normal human standard, was required to kill the ordinary micrococcus of pus or the bacillus of typhoid fever. The absence of spores was insured in every case.

Next Macfadyen followed up his test experiments with some on the dog. Dogs fasting for twenty-four hours were fed with foods containing pure cultures of the pus micrococcus, and killed after five hours. All showed large numbers of the aureus throughout the digestive tract, and especially numerous in the lower parts. Dogs not fasting gave the same results.

Lastly, Macfadyen tried to pass the more perishable forms through the stomach, and found that by giving a thirsty dog water, containing the culture, to drink, any form could be introduced into the intestines, even the cholera bacillus. Under such conditions, common ones among men during hot weather, and notoriously unhealthy, the water scarcely stops in the stomach,

[7] Macfadyen. Journal of Anat. and Physiol., 1887, Vol. XXI, pp. 227 and 413.

but passes through the pylorus almost as soon as swallowed.

It is thus clear that the stomach offers but an insecure protection, many forms outlasting the test of full digestion in the dog, and any form being able, under natural conditions, to pass the stomach. The dog's stomach is a fair test, since the acid is the active principle, and more abundant than in man.

That the bacillus of tuberculosis can pass the stomach, as shown by feeding experiments, is well known to all.

Of the morphology and biology of the forms found in the stomach little is known. The field is a new one, and the species have not been sufficiently described to enable others to recognize them with certainty. Miller has found five kinds which give off carbonic dioxide and hydrogen gas, lactic, acetic and butyric acids being formed. In some cases an inflammable gas is known to have been formed in the stomach, probably marsh gas.

Of the flora of the intestines much more is known than of that of the stomach, thanks to the work of Bienstock, Miller, Brieger, Vignal and Escherich, not to mention the facts brought out in the study of typhoid fever and cholera.

Bienstock[8] was the first to attack the subject by means of cultures. Unfortunately his methods were inexact, and he shut his eyes to facts long revealed by the microscope. This led him to claim the existence of only four or five kinds of bacilli in the fæces, hence in the intestines, and to deny the existence of micrococci. To one of the forms he attached special fermentative and digestive powers, which he held were of decided assistance to the process of digestion; thus

[8] Bienstock. Fortschr. d. Medicin, 1883, p. 609; Zeitschr. f. Klin. Med., 1884, p. 1.

from experimental grounds advancing Pasteur's idea that, were it not for the action of the bacteria in the intestines our digestion would fail, and human life become impossible, — a very pretty theory which has by its sensational nature recommended itself to many, but has failed to find support in facts, as yet discovered. In his last article Bienstock entirely dropped this subject, and it is only mentioned here as it has found its way into not a few books.

The last form described by Bienstock is his drumstick, a very powerful decomposer of albumens, and not to be found in the fæces of sucklings. In regard to this form Bienstock again seems to be in error. No one else has found it, but it has been shown to be a very dangerous source of contamination of the various nutritive media employed, being very hard to kill. Escherich at one time described the form as occurring, but later found it to be a contamination.

The researches of Brieger,[9] Vignal,[10] Stahl[11] and Escherich,[12] have now proven that a large number of species may occur in the fæces. Brieger isolated two new kinds, one a micrococcus, which turns grape or cane sugar into ethylalcohol, with a trace of acetic acid; the other, the well known Brieger's bacillus. This species occurs in vast numbers in the fæces, ferments sugars and decomposes albumens.

Vignal isolated ten species from the fæces, six of these being also found in the mouth. Of these some produced acid fermentations and gas. Unfortunately

[9] Brieger. Zeitschrf. f. Physiol. Chem., 1884, p. 306.
[10] Vignal. Archiv. de Physiologie, 1884, p. 492.
[11] Stahl. Verhandl. des III Congress f. inñere Medecin, 1884.
[12] Escherich. Die Darmbacterien des Säugline und ihre beziehunger zur Physiologie der Verdanuung, 1886. Also for shorter notes see Deutsch. Med. Wochenschrift, June 14, 1886, Therap. Monatshefte, Vol. I, 1887, p. 380; Centralbl. f. Bacteriologie, Vol. II, 1888, p. 644; Fortschrit. d. Median, 1886, pp. 515 and 547.

they were not studied sufficiently to show their effects on digestion.

Miller has already been referred to in treating of the stomach; the inaugural dissertation of Kuisl,[13] has not been seen.

This brings us to the work done by Escherich, and the conclusions to be drawn from the same. This author studied the fæces of infants, the intestinal contents at autopsies, and found a large number of kinds. Among them, a small bacillus capable of converting milk sugar into lactic acid, carbonic dioxide and hydrogen gas being evolved, either in the presence or absence of air — in scientific parlance, a falcultative anaërobic species, his bacillus lactis aërogenes. Escherich also studied and described at length the action of Brieger's bacillus under the name of bacillus coli commune.

Both of these forms are fatal to guinea-pigs and rabbits when introduced into the venous system. Post-mortem examination, showing the spleen and kidneys normal, marked injection of the upper part of the intestine, mucous membrane swollen, chyme thin, alkaline, mixed with much mucus, Peyer's patches appearing as swollen, resistant, bluish-red spots through the serous coat; in places, superficial epithelial loss. With Brieger's bacillus, diarrhœa also occurred at times.

In addition to the two pathogenic forms just mentioned, Escherich found proteus vulgaris in meconium streptococcus coli gracilis, bacillus subtilis, and several other forms of less interest.

The great point is that by the examination of a large series of cases Escherich has been able to establish the fact that the kinds occurring in the fæces vary with the food; that is, the intestinal contents.

[13] Kuisl. Darmbacterien. Inaug. Dissert. München, 1885.

Starting at birth with the sterile meconium, consisting of mucous, epithelium and the like, infection by the mouth and rectum quickly occurs, and in a short time most any form may be found, but chiefly putrefying forms, as proteus vulgaris. With the suckling of the child and the substitution of the refuse of the milk and secretion of the digestive tract for the meconium, a sharp transition occurs. Instead of the generally distributed forms causing decomposition, only two kinds are regularly found: B. lactis aërogenes and Brieger's bacillus; the first chiefly in the upper parts of the intestine, the second in the lower parts. Passing on to the period of mixed diet, quite a number of forms appear, among them the streptococcus coli gracilis, the putrefying green fluorescing, a tetrad coccus, and several kinds of yeasts. This brings us to the pith of the subject: why are the flora so limited in the milk-eating infants and so diverse in others? What drives the forms found in the meconium out? That they can live there is clear, as shown by their presence the day before. Again, what prevents forms so common with meat diet from gaining a footing? It is not the milk alone, for milk is an almost universal food for bacteria, and all the kinds found in the intestines thrive in it.

Escherich answers as follows: the bacillus lactis aërogenes and the milk diet keep out the other forms.

Formerly, even before the nature of ferments and putrefactive processes were clearly understood, the significance of this question was seen. The chyme is a mass admirably adapted for putrefaction or fermentation, yet, ordinarily, but little of either occurs. It is an alkaline, or, as in the milk-fed, acid mixture rich in albumens, fats, and the starch group, amply provided with water and warmth. Such a mixture outside the body at an equal temperature would quickly

decompose. It was generally held that some preservative action was exerted by the digestive juices; Bidder's and Schmidt's dogs with biliary fistulæ were held to explain the whole. These dogs, deprived of their bile, became emaciated, and suffered from diarrhœa and decomposition of the intestinal contents. Thus it seemed clear that in the absence of the bile decompotion occurred; that is, that the bile was a powerful germicide or germ-inhibitor. During the last few years, however, different results have been obtained in cases of biliary fistula. Röhmann's[14] dogs did not suffer from diarrhœa or putrefaction in the intestines; hence it is clear that the bile is not the cause of prevention. The diarrhœa, if present, is due to the large amount of fat passed on to the lower intestines.

Maly[15] and Emich[16] ascribed value to the bile acids, especially the taurocholic, basing their results on crude methods; and Lindenberger,[17] really leaving the subject, attributed the action to the organic acids in combination with the bile.

All this argument and belief in the decided germicidal action of the bile occurred in the face of the well-known fact that bile itself will decompose.

From a bacteriological standpoint, Miller has shown that a ten per cent. solution of bile, if anything, favors growth. Macfadyen has studied bile, bile salts, and bile acids in varying strengths. The only positive results were got with the acids, these arresting development of bacteria if sufficiently strong, especially taurocholic acid. Neither acid had much effect, and least of all on the forms causing putrefaction. Proteus vulgaris was only arrested by a strength of

[14] Röhmann. Beobachtungen an Hunden mit Gallenfistel. Breslau, 1882.
[15] Maly. Hermann's Physiologie, v, p. 184.
[16] Emich Sitzberich. d. Akad. d. Wissenshft. Wein., 1882.
[17] Lindenberger. Upsula Forhandlingar, 1884.

from one to two per cent. The pathogenic forms were arrested by a much smaller quantity, from one to one-half per mille.

It is thus clear that other causes must be sought for. One of these is to be found in the lack of oxygen in the intestines, as pointed out by Escherich and strangely forgotten by others. There is certainly very little free oxygen in the chyme, if any; not only is it scarce in the food at the start, but is taken up by the chemical changes during digestion, and also by the intestines. This clearly must be a potent factor, for the majority of bacteria require a fair supply. Accordingly, many bacteria are found in the fæces which will not grow in the air, as shortly stated by Macfadyen, and the mass of those isolated in the air are able to grow without it.

This apparent contradiction, the absence of oxygen in the intestines, and the presence of both aërobic and anaërobic bacteria is probably explained by the ability of the aërobic kinds to drawn oxygen from oxyhæmaglobin. They thus breathe through the intestines, as it were, when in close contact with the walls, while the anaërobic kinds live in the mass of the chyme, and do not, so far as we know, reduce oxyhæmaglobin.

Escherich, though he points out the absence of oxygen, does not seem to give it full value, or rather forgets the subject in treating of the action of his lactic acid bacillus. As before stated, this form is regularly found in great numbers in the upper part of the intestines of milk-fed children. Here it converts a considerable part of the milk-sugar into lactic acid (Baginsky [18] says acetic acid, but has given no proof), and thus prevents the other forms from growing, most forms being very susceptible to an acid reaction,

[18] Baginsky. Deutsch. Med. Wochenschr., 1888, Nos. 20 and 21.

and especially to the organic acids. The action of salicylic acid is known to all, and recent experiments, of which Macfadyen's (the last are the best) show acetic, butyric, and lactic acid to be efficient germ-inhibitors in strengths of from one to one-half per mille, according to the species.

In milk-fed infants another point is the comparative inability of bacteria to attack casein, so that the bacteria are literally starved.

To sum up, we may conclude that the bile acids, lack of oxygen, lack of suitable albumens, and the presence of organic acids are the causes of immunity from the putrefying and fermenting kinds of bacteria to which we are exposed. Certain forms are probably limited by the lack of water, that is, fluid state, doing poorly if unable to swim freely about. It must not, however, be supposed that bacteria are scarce in the intestines, on the contrary they form a large part of the dry substance of the fæces.

Brieger's bacillus has been passed by us as of no importance in reference to the above. It thrives in the lower part of the intestine, feeding on the refuse passed on from above, and secretions and excretions of the tract. The species has a fermentative action, producing alcohol and a trace of acetic acid (Brieger), a powerful action on proteids and breaks up fats (Escherich).

Passing from the normal condition of the intestines to those of indigestion and diarrhœa, more especially of infancy, while there is little worked out to a conclusion there is much of value to be applied in treatment. It is known that in the cases of indigestion accompanied by the eruction of gas and not a few cases of vomiting bacteria are playing an important role, often are the causes. Such cases of indigestion are usually characterized by the eructation of gas after

meals and a sense of oppression due to the disturbed digestion and dilatation of the stomach. A certain small amount of lactic acid occurs in our food, the same is true of acetic acid, but butyric acid should be practically absent. In normal digestion a small amount of the first two is of no harm, and one of them seems to play an important part in the upper part of the intestines. Butyric acid is an offensive compound and acts as an irritant in the stomach. Any of these acids produced in quantity in the stomach are injurious, tend to cause and keep up catarrh. The gas given off during the production of the acids not only oppresses by unduly dilating the stomach, but must interfere with the mechanical action of that organ. We now know that the stomach does not lie across the body but more up and down, the pylorus being below. In this position the food tends to fall to the pylorus and is constantly worked up towards the cardiac end by muscular action, the more fluid parts running back and down into the duodenum. Gases, easily compressible as they are, must interfere with this pumping or driving motion and render the mechanical work of the stomach less effective impeding an intimate mixture of the food and gastric juices and thus hindering proper digestion.

As pointed out by Taube,[19] since the stomach dilates chiefly on the side of the greater curvature, hyper-extension brings the curvature below the pylorus. In this case all fluids will gravitate to the pocket thus formed instead of to and through the pylorus.

Recently Klemperer,[20] in studying the hydrochloric acid in the stomach has developed the fact that much of the disagreement as to the hydrochloric reaction in cases of cancer of the stomach, and dilatation depends

[19] Taube. Schmidt's Jahrbücher, 1887.
[20] Klemperer. Zeitschr. f. klin. Med., 1888, p. 147.

upon the bacteria contained in the juices. The bacteria act in two distinct ways. First, according to the well known law that a mixture of acids combine with a base in quantities according with the strength of the acids, the various organic acids produced by fermentation drive out a small part of the hydrochloric acid. Second, other products of the bacterial growth as the ptomaines, form compounds with the hydrochloric acid sufficiently strong to prevent the bluing of methyl violet, but not sufficiently strong to resist the other tests commonly used. The acid thus combined is taken away from the digestive process, which is proportionately weakened. In normal digestion the amount of hydrochloric acid thus taken up varies from .6 to 1 %, while in a case of cancer it rose to 2.5 %.

Klemperer worked not only with the ptomaines produced by the growth of Brieger's bacillus in milk, but also with those isolated from the gastric juice in a case of cancer of the pylorus.

The diarrhœal troubles of adults have not been sufficiently studied bacteriologically, and little is known of them. In a few cases examined by myself the proportion of Brieger's bacillus to the other aërobic forms has been reduced, and two or three putrefying forms decidedly increased, among these the putrefying green fluorescing. Pure cultures of this plant give off an offensive odor closely resembling those of the stools from which they were taken.

In this connection it is interesting to note that the period of raw small fruit, salads and the like, is the period of intestinal troubles. In other words, the consumption of raw — that is, not sterilized — foods, which by their nature and surroundings are exposed to all sorts of bacteria, goes hand in hand with the prevalence of functional intestinal trouble. The small fruits are eaten whole, together with a hoard of bac-

teria, large fruits eaten later are peeled, that is, prepared, much like a potato for a pure culture.

On the whole, bacterial overgrowth in the stomach tends to the so-called ferments in the intestines to putrefaction.

Of the summer diarrhœas of infancy we really as yet know nothing specifically. Bacteria are very abundant, the putrefying group coming forward. Lately Escherich, in an article of which I have only been able to procure a notice, reports that the spiral forms are unusually abundant in cases of diarrhœa, but regards them as a result rather than cause of the trouble.

The only claim worthy of consideration to the discovery of a specific organism has been put forward by Lesage.[21] This author describes a form as constantly occurring in great numbers in the stools of a certain class of diarrhœas, the clinical aspect of which corresponds with an ordinary case with an elevated temperature. This plant produces a green coloring matter, is easily grown, and, according to the author, has a very bizarre method of development. Not only does the plant show a tendency to grow into threads, later splitting up into bacilli, but it produces endogenous spores, which in turn give off a number of daughter spores by budding, these growing into bacilli and threads. So far as known to me this is an utterly new method of growth among bacteria, indeed, removes the plant entirely from the class. Another peculiarity is that the spores are more rapidly and deeper stained than the vegetative cells. This plant, Lesage states, produces green diarrhœa if introduced into the intestines or stomach, and one syringe full introduced into the ear vein of a rabbit produced a slight green diarrhœa. The plant was recovered in the intestines. Pure cultures were found to be quite sensitive to lactic acid,

[21] Archiv de Physiol., 1888. Feb. 15th, p. 212.

so Lesage adopted a lactic acid treatment for these cases, giving large doses, and reports extremely favorable results, in fact, a specific action.

As yet no confirmation of Lesage's observations have come to hand. My own search for the plant in the few suitable cases to be found so early in the year have failed. The nearest thing to it found was the putrefying green fluorescing bacillus. This has a green color, but lacks all the other characteristics of Lesage's plant. Baginsky has discredited Lesage's results, and considers the plant to be the green fluorescing bacillus, which it certainly is not, for the plant has no such mode of growth. The entire thing is very strange, and needs abundant confirmation before being accepted. At the present time there seems to be no reason to expect a specific, but rather that the whole trouble begins as a reaction to noxious products of various species and runs on in the course of time from a condition of pathological physiology to one of pathological anatomy, loss of substance occurring in the epithelium.

With the growth of our knowledge of the active part played by bacteria in the various troubles of the alimentary canal a decided change has occurred in the treatment of the same. These changes have for the most part been instituted without any clear idea of their action, survived in virtue of their efficacy, to be later modified, perfected and guided by the light thrown upon them by bacteriology.

The recent changes in the treatment of gastric catarrh so ably presented in this journal by Knapp, at once reveal the fact that an efficient anti-germ treatment is now followed; not only is the stomach washed out, that is, the field weeded, but the soil mucous and refuse of food is removed, and a weak poison left in its place at times. The well-known use of creosote,

sublimate and calomel probably owe their utility to their impairing the bacterial growth. Various efforts have been made to kill the unwelcome guests in the intestines by means of drugs. In the diarrhœas of infancy this subject has been attacked from three sides, by the use of drugs, by the care of the food, and by change of diet. All three methods are rational and worthy of use, often together. Other things being equal, modern physicians would eschew drugs, and the laity rush for them. They would rather take medicine than trouble. From a therapeutic side efforts have been made to find something to kill the plants and not the child. These drugs may be classed as mild antiseptics, as organic acids and antiseptics, soluble and insoluble. Barring Lesage, there does not seem to be any strong enthusiast in favor of the acids; though the curative effect of sugar has been pointed out by some. Sugar acts by being changed to acids in the intestine. With the germicides there is still quite a rage, due in large part to the assumed destruction of the germs. As a fact the germs are only slightly reduced in numbers by the most successful drugs. A drug to be antiseptic must be soluble, if soluble it is at once taken up by the intestines, thus being removed from where it is wanted and put where it is not wanted in the child's system. If insoluble, or rather slowly converted into a soluble active form, the action is weak, and absorption still occurs, only in small quantities throughout the gut instead of all at once in the upper part. Reasoning gives hope of but slight success with germicides, while the great number of things recommended strongly suggests insufficiency of all. Were any drug markedly successful the others by selection would quickly be excluded.

Again, if, as appears, Escherich's ideas of the value

of his lactic acid bacillus are correct, we would by the use of germicides only open the field to any form that might chance to gain access.

Possibly there is hope of better results to be obtained by the use of drugs directed, not to the destruction of the germs, but to the alteration of their poisonous products. No effort seems to have been made to attain this result, except by the administration of acids and alkalies. I have suggested that iodoform [22] may have this effect. It certainly removes odor from putrid fluids quickly, though it does not kill the bacteria. This may be a simple case of concealment, but as the effect is a half-hour in development it is doubtful. We know that the administration of iodoform removes the aromatic compounds from the urine. Unfortunately, iodoform is decidedly poisonous, causing fatty degeneration, and its products secreted in the saliva combine with the metals of our eating utensils to form most revolting compounds in the mouth.

Naturally it has long been the custom when the infant suffered on one kind of food to change to another. Thus peptone solutions, albumens, and various starch and dextrine solutions are still much used; to say nothing of the various patent foods consisting when given, of cow's milk, starch and its derivatives. Wine whey, a very old preparation, seems to have dropped out of use in this vicinity, but still holds its own in England and Ireland.

All these efforts to find a more satisfactory food have been the natural result of failure, and directed purely on empirical grounds; often change after change being made until a successful food was hit upon or the child died. Escherich's work now opens

[22] Jeffries. Am. Jour. Med. Sciences, 1888, January. Behring has just shown this to be true of cadaverin. Deutch. Med. Woch., Aug. 9, 1888.

the field to more intelligent work. The secret of the value of change of food according to him lies in the effect upon the bacteria. Some of these attack the starches, others sugars, or both sugars and starches, while at the opposite end of the series albuminates are attacked and putrefaction results.

Either group, ferments or putrifiers, is undesirable. The ferments act by the production of various acids, chiefly from the milk sugar. In small amounts, as in the case of bacillus lactis aërogenes, the acid seems to be of benefit, certainly does no harm as it regularly occurs in healthy breast-fed infants. In larger amounts, however, it must tend to over-acidify the contents of the intestines and upset the action of the digestive fluids.

Bokai [23] has recently shown that the various organic acids have a very decided effect on the motion and blood-supply of the intestines. The intestines of rabbits were exposed in a warm normal salt solution bath. All the acids were found to increase peristalsis, lactic, succinic and acetic acid with constriction of the bloodvessels; valerianic, butyric, formic, proprionic, capric and caprylic acids with dilatation of the same. One or two grammes exhibited by the mouth produced diarrhœa, smaller doses a catarrhal state, and larger a positive inflammatory state.

These observations pave the way to Baginsky's theory, practically an acceptance of Escherich's ideas, that the lactic acid bacillus growing in superabundance irritates the digestive tract, causing diarrhœa, and if continued, brings about its own death by the superabundance of acid produced. In this case the acid is quickly passed on and the gut is left open to the putrefying alkali frequenting forms.

[23] Bokai. Archiv. f. Experim. Path. u. Pharm., 1887. Vol. xxiv, p. 153.

The value of Escherich's work here comes in; he suggests that the change of food should be governed so as to starve out the rampant ferment. If the ferment is an acid one, to give a food free from sugars and starches, if an alkaline one, free from albumens and calculated to encourage the lactic acid bacillus to a normal growth. In the first case Escherich suggests peptone solutions, in the second, dextrine solutions.

Baginsky accepts Escherich's principles, but claims that he has forgotten the child and that empirics have their place. He points out that peptones are known to be poisonous if introduced into the system, and often cause diarrhœa. Unfortunately, Baginsky is not clear as to what should be given. Dextrine is also objected to on account of the impurities contained and milk sugar suggested as a substitute.

Lastly, Escherich has refuted Baginsky's objections and referred to the favorable results obtained by Ehring. That cane sugar, glycerine, dextrine and starch stop putrefactive processes in the intestines is proved by Hirschler's experiments. This author showed that the products of decomposition were absent in urine and fæces of animals treated with these foods.

Baginsky attaches great value to calomel in the early stages, on purely empirical grounds, since Morax has shown that the drug does not affect the aromatic group.

It is probable that kephir will prove to be a valuable food in the cases of acid diarrhœa. This is milk fermented by the kephir grains composed of two or more kinds of bacteria. By the growth of the plants the milk sugar is broken up; alcohol, lactic acid, carbonic dioxide and hydrogen being formed. The injurious constituent of the milk, the sugar, is removed, and the casein is curded in fine flakes and so cannot form a mass in the stomach.

Is the reaction of the stool a sufficient index to the ferment in the intestine? Escherich thinks it is, Baginsky and Vaughn [24] doubt it. Here the study of the urine by Morax,[25] Baumann,[26] and Hirschler [27] come into play. These authors have shown that the sulphuric ethers and aromatic compounds of the urines vary with the amount of putrefaction in the intestines. Thus by a quantitative analysis an exact knowledge of the ferment is to be obtained.

Though not treating of bacteria in the intestines, Vaughn's work on tyrotoxicon cannot be passed by, and leads the way to the last and most radical part of the subject, prophylaxis. Vaughn has isolated from milk, ice-cream, and the like an active poisonous compound, which produces symptoms much like those of cholera infantum. This compound, diazobenzol, is produced in milk excluded from the air, and at a temperature of at least 60°. The bacterium producing the trouble has not yet been found. It is very likely an anaërobic species.

Vaughn's article suggests that the tyrotoxicon plant may be the cause of cholera infantum, but does not frame the idea.

Very recently, Behring [28] has announced that cadavarin, pentamethylindiamin, produces death in guinea-pigs, with symptoms and post-mortem resembling Koch's artificial cholera in the same. Cadavarin is freely formed by the cholera bacillus in alkaline solutions, commonly occurs in decaying bodies, as indicated by its name, and may be, therefore, an element in the diarrhœas of infants and adults.

Taking up the subject of prophylaxis, it is clear

[24] Vaughn. Medical News, 1888. Practitioner, 1886, p. 232.
[25] Morax. Zeitschr. f. physiol. Chem e, 1886, p. 318.
[26] Baumann. Zeitschr. f. physiol. Chemie, 1886, p. 123.
[27] Hirschler. Zeitschr. f. physiol. Chemie, 1886, p. 306.
[28] Behring. Deutsch. Med. Wochens ift, June 14, 1888.

that the general laws of health must be attended to, that mother's milk is better than cow's milk, and, as shown by Rotch,[29] that quantity and quality of all foods must be attended to. Over and above this, the feeling that the summer diarrhœas are due to changes in the food, that is, to bacteria in the same, has been steadily gaining ground for some time.

With this consideration in view, great care has been given to the food-supply, ice employed, and the like; also cooked food given.

In 1886, Soxhlet[30] published an article recommending the sterilization of milk by immersion in boiling water for forty-five minutes, the flasks containing the milk to be closed after being heated. Soxhlet made no bacteriological study of the subject, and simply took the curdling of the milk as a sign of infection. Measured by this standard, the milk kept about three weeks. Unfortunately, milk becomes full of bacteria and seriously altered before curdling occurs, and certain species do not curdle milk. Soxhlet kept the deadly, long sucking-tube, and advocated a very complex apparatus of bottles, cages, and water-baths.

In the summer of 1884, my attention was first directed to steaming the milk for infants, being guided by the custom of housewives. Receipts are to be found in the cook-books for preserving milk and cream for a long time, the principles of which are the addition of a moderate amount of sugar, then bottle, and all to be heated in boiling water for some time, the cork, also scalded, to be driven home while the whole was hot. In short, the whole of Soxhlet's method packed in a nutshell.

In 1887, on returning from Europe, my attention was again called to the subject, and every child under

[29] Rotch. Archiv. for Pediatrics, August, 1887.
[30] Soxhlet. Münch. Med. Wochenschrift, 1886, p. 258.

my care put, as far as possible, on steamed milk. Being pleased with the results, and learning that Dr. Ernst had used a similar method for three yeara, I determined to work the subject out from a bacteriological point of view, and obtain some reliable, simple method capable of general cheap application. The results were published in a paper,[31] from which I quote :[32]

"Stopper the flasks (that is, those from which the child is to be fed) with cotton-wool, and heat them in the oven for thirty minutes at a mild baking heat, or until the cotton becomes brown. Pour the requisite quantity of food into the flask, and then place in the heated steamer for fifteen minutes."

If this method is followed, the milk will keep for a long time practically free from bacteria and their injurious products. The first rule is a refinement, and, in view of the work of Wolfhügel and Beidel,[33] desirable. These authors have shown that pathogenic germs in washing water could cling to the vessels and infect milk put in them.

The steaming must be thorough, but any simple steamer will do, provided it is filled with live steam. The milk should be steamed *at once* on receipt from the milk-man; otherwise the child will get a sterile food already charged with the poisons of decomposition.

No expensive and complex apparatus is needed, and on a pinch an ordinary medicine-bottle placed in the tea-kettle will nearly fill the requisites. Cotton-wool is the proper stopper; it cannot be blown out, hence

[31] Jeffries. Am. Jour. Med. Sciences, May, 1888.

[32] Soxhlet's article was not referred to in my paper, as I did not then know of it, nor, indeed, have I been able to find any person present at the time it was read who had seen Soxhlet's article.

[33] Wolfhügel u. Riedel. Arbeit a. d. kaiserl. Gesundheitsamt., I, 1886.

can be put in before steaming, and is germ-tight. Any stopper put in after steaming is not itself disinfected. When the child is to be fed, take out the cotton plug and put on a short rubber nipple. It is absurd to struggle with a sterile mouth-piece so long as the infant's mouth is swarming with bacteria: the value of the method lies in the integrity of the milk.

We thus see that a good start has been made, much knowledge gained, and much to be looked for. The very gaps in our knowledge show that the subject is a far-reaching one. Bacteria form a part, perhaps large part, in the balance of forces in the intestines, which results in normal digestion. Any disturbance, be it from the food, bacteria, or the intestines, throws the balance out and results in disease.