STUDIES UPON THE TOXICITY OF PUTRID FOOD.

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In nearly every case where canned meat or fish is condemned as unfit for human consumption, the action is based upon the physical features of the unopened tin, which are held to indicate decomposition of the contents. No studies of canned foods would therefore be complete without some detailed consideration as to the real harmfulness of such rejected foodstuffs.

In view of the large quantity of tainted and unsound food rejected and destroyed annually, it is surprising that so few data exist as to the precise nature of the harmful substances in such food so that scientific reasons can be given to justify so extensive and widespread an administrative practice.

Existing evidence is both meagre and unreliable. Three fallacies vitiate nearly all the data we possess and render unreliable the conclusions drawn from the recorded facts.

The first of these fallacies is that the alleged harmfulness of meat or other foodstuff in a condition of incipient putrefaction has usually been confused with poisoning by food infected with specifically harmful bacteria. This is clearly brought out when the bacteriology of outbreaks of food poisoning is studied. At one time such outbreaks were widely and indiscriminately ascribed to changes in the food of the nature of putrefaction. More careful investigation has shown that the vast majority of such outbreaks are due to infection of the food by certain specific and highly pathogenic bacteria which are incapable of initiating putrefactive changes.

When outbreaks with this etiology are removed from the list it is found that those for which a definite putrefactive origin can be adduced are reduced to a vanishing point, and it is not too strong an inference to draw from the recorded outbreaks that no extensive outbreaks of food poisoning have ever been shown to be due to the consumption of food in a putrefactive condition, unaccompanied by a definite specific bacterial infection or the presence of toxins produced by such specific bacilli. It is not possible to exclude entirely a putrefactive origin in these cases in which individuals, or even small groups of individuals, have suffered, because the scientific records are so meagre, but diligent search has not revealed a single case in which the evidence proved that the attack was due to putrefaction uncomplicated by pathogenic non-putrefactive bacteria.

The second fallacy is that the chemical studies upon which the theory of the harmfulness of food in a condition of putrefaction has been built up rest upon a study of the end products of putrefaction and not upon an investigation of the toxicity of such foods in stages of putrefaction when there is a possibility of their being consumed. The whole ptomaine theory, built as it is upon such foundations, is entirely unsound.

The remaining fallacy is that nearly the whole of the evidence as to the alleged toxicity of the products of protein decomposition is based upon experiments upon animals in which the method of introduction is by injection and not by feeding. The introduction of the products of decomposition, alien as they are to the animal economy, directly into the tissues might be expected to produce intoxication which would not occur if the product had been introduced by the mouth and been subject to the action of the digestive juices. It is well known that there are a number of substances such as snake venoms and products of pathogenic bacteria, which are nearly harmless by the mouth but intensely toxic when introduced under the skin.

In view of the remarkably scanty evidence upon which the theory of the harmfulness of incipiently putrefactive food has been built up, it seemed advisable to test directly the harmfulness of food in the early stages of putrefaction, and the following experiments were therefore carried out as a small contribution to this difficult subject.

Experimental Investigations.

In the majority of the following experiments young kittens were selected as being the most suitable. They are more akin to man in the physiology of their digestive system than the usual laboratory animals, while the fact that they vomit readily is an important advantage in work of this character.

Owing to the work being carried out in association with other investigations, inability to obtain suitable animals just when wanted, etc., the actual experiments, although few in numbers, were spread over several years. The first ten experiments were carried out by me alone in 1918. Experiment 11 (in 1919) with the assistance of Mr R. B. Calder and Experiments 12 and 13 (in 1920) with the help of Mr Hunwicke.

Exp. 1. Raw meat was taken and kept at laboratory room temperature for three days when it became very offensive and putrid. Washings from the pulped meat strained through muslin were mixed with the rabbit's food and fed to the animal on three consecutive days. The animal showed no loss of weight and no ill effects of any kind.

A second rabbit was injected subcutaneously with 1 c.c. of the washings. The animal showed no obtrusive symptoms for the first two days, was noticeably weak and ill on the third day and died on the fourth day after the injection. A post-mortem revealed no gross lesions, and cultivations from the spleen and liver (both aerobic and anaerobic) and from the heart-blood (aerobic only) were all negative. There was no inflammation at the site of inoculation.

Although no bacteria were isolated, the length of time suggests bacterial infection from the putrid emulsion.

This experiment is of interest as an illustration of the fundamental differences between introduction by the mouth and under the skin.

Exp. 2. A young kitten, weight 447 grms., was fed on six consecutive days with the emulsion (obtained by pulping and straining as for Exp. 1) obtained from very putrid meat. The first day the method of feeding was by direct introduction into the stomach, but on the other days it was found possible to get the animal to drink the dose (about 20 c.c.) by mixing it with an equal quantity of milk and giving no other food until it was consumed.

Throughout the experiment the animal showed no symptoms and remained active and apparently unaffected. During the period of feeding the gain in weight was only 10 grms., but when killed at the end of 23 days the weight had increased by 52 grms., or 11·6 grms. per 100 grms. of body weight. A control kitten over the same period fed with similar food, but without any putrid meat extract, gained 79 grms., or 15·5 grms. per 100 grms. of body weight. The experimental kitten, when killed, was very thin in appearance and a post-mortem showed a muscular development well below the normal. Microscopically the organs appeared sound. No bacteriological cultivations were made.

While the nutrition of the animal was somewhat interfered with no active symptoms of ill health resulted and nothing in the nature of food poisoning.

Exp. 3. A young kitten, weight 460 grms., was fed on three successive days with putrid meat washings from shop beef allowed to putrefy naturally. Putrid emulsion from about 20 grms. of meat given each day. The animal remained well and increased in weight. Killed 11 days after the last feeding. The animal throughout exhibited no symptoms while post-mortem the kitten was found to be fairly well nourished and showed no lesions.

Exp. 4. A kitten, weight 645 grms., was fed on three consecutive days with an emulsion (obtained as above) from a mixture of two tins of corned beef very badly blown, with putrid very offensive contents. Emulsion from 30 grms. used for each feed.

The meat showed a great variety of bacteria including *B. proteus* but no anaerobes were isolated.

The kitten showed no symptoms of any kind while no naked eye lesions were present when killed nine days after the last feeding. No microscopic lesions observable in sections from the stomach and small intestine.

The animal showed an increase of weight of 72 grms. during the 12 days and this was only slightly less than that of a control kitten.

Exp. 5. This and the next experiment were designed to test the relative toxicity of the bacteria of putrefaction and of their products separately. Fresh meat was allowed to putrefy naturally at 21° C. for several days. An emulsion in warm water was made by mixing and pulping and allowing to stand at 37° C. for an hour.

The very turbid and offensive liquor, after straining through muslin, amounted to about 15 c.c. obtained from 20 grms. of meat. This was centrifugalised for three quarters of an hour and the liquid then filtered through a porcelain filter. A clear sterile fluid was obtained.

A young rabbit injected subcutaneously with 4 c.c. of this fluid remained perfectly well and showed no symptoms.

The centrifugalised deposit was repeatedly mixed with sterile water and recentrifugalised to wash it free from any toxins. Another young rabbit injected subcutaneously with a considerable quantity of this washed deposit mixed with a little water showed no symptoms and remained quite unaffected.

Exp. 6. Raw fresh meat was allowed to putrefy naturally at 21° C. for 48 hours. A very rich bacterial emulsion was then made by scraping off the surface bacteria first, then pulping the meat and keeping it mixed with sterile water, and with the surface bacteria, at 37° C. for two hours. The liquid was then strained through muslin. Three experiments were made:

(*a*) A rabbit injected subcutaneously with 1 c.c. of the untreated turbid and offensively smelling emulsion remained quiet but not obtrusively ill for the first 24 hours, but was moribund and killed about 48 hours after the injection. A post-mortem examination revealed blood-stained exudation and great redness of the subcutaneous tissue and muscles at the site of the inoculation and *B. welchii* was isolated from this lesion. No abnormalities internally.

(*b*) The supernatant fluid after centrifugalisation was filtered through a sterile porcelain filter and 3 c.c. of the clear filtrate injected into a young rabbit. No symptoms resulted and the animal remained well.

(*c*) The centrifugalised deposit after well washing and recentrifuging three times to remove extra-cellular toxins was injected subcutaneously into a guinea-pig (a rabbit was not available). The animal was quiet but not obtrusively ill next day, but was found dead on the following day. Very typical *B. welchii* infection lesions while *B. coli* was also isolated. The small intestine was full of fluid with a strong putrid odour. The other internal organs appeared normal but *B. coli* was isolated from both the liver and the spleen.

Exp. 7—to test the toxicity of the sterile products of putrefaction. Meat, after moistening, was kept at 21° C. in a covered glass jar (*i.e.* under semi-anaerobic conditions) for five days. An emulsion was made in the usual way from the green and very putrefactive meat. The strained liquid was filtered through a sterile porcelain filter, 5 c.c. of it being the filtrate from about 15 grms. of meat, and injected intraperitoneally into a kitten of weight 542 grms. The animal remained perfectly well throughout the experiment but lost 57 grms. during the first seven days following the injection; its weight then slowly increased and 17 days after the injection it had reached the weight recorded at the start of the experiment.

Exp. 8. A young kitten, weight 572 grms., was fed with an emulsion from raw meat allowed to putrefy naturally at 21° C. The emulsions were obtained as in the previous experiments. The first feeding was after two days natural

putrefaction. Six feeds on consecutive days were given, the last therefore being after eight days' putrefaction.

During the six days of feeding the animal gained 5 grms., then alternately lost and gained weight, and when killed 32 days after the first feeding it was 590 grms. In 32 days therefore the gain was only 18 grms. instead of about 160 which would be about the normal growth increase in this period.

The kitten remained perfectly well throughout without any evidence of gastro-intestinal disturbance or other symptoms.

Post-mortem showed the animal to be fairly well nourished with no lesions anywhere, while cultivations (aerobic and anaerobic) from both the liver and spleen were sterile. No putrefactive anaerobes could be cultivated from the small intestine.

A study was also made of the excreta of this kitten during the course of the feeding to try to discover and isolate putrefactive organisms. No putrefactive anaerobes were found but *B. proteus* was isolated. *B. proteus* was abundant in the putrid meat itself but proteolytic anaerobes could not be isolated.

Exp. 9. A feeding experiment with putrid canned meat obtained from a very blown 6 lb. tin with very offensive contents. The bacteriological examination showed *B. proteus* abundantly present and in pure culture, anaerobes and other bacilli being absent. This *B. proteus* strain was pathogenic to a mouse by subcutaneous injection and was recovered from the liver and heart-blood. A kitten was fed on four successive days with the emulsion from about 60 grms. for each feed. No vomiting, diarrhoea or other symptoms of illness occurred while the animal remained lively and active. It, however, suddenly became ill one morning and died seven days after the last feeding.

The kitten weighed 540 grms. at the time of the initial feed and its weight steadily declined to 417 grms., *i.e.* it lost 123 grms. over the 11 days' period between the starting of feeding and death.

Post-mortem the animal was found to be extremely thin, but there were no naked eye lesions in the alimentary tract or indeed in any organ. Aerobic and anaerobic cultures from the liver, spleen and heart-blood showed a few *B. coli* colonies but no *B. proteus*. *B. proteus* could not be isolated from the large or small intestine although it was quite easily isolated from the meat used for the feeding.

Microscopic sections from the small intestine of this animal and also from a number of the other kittens showed no pathological changes.

Exp. 10. Since Experiment 9 suggested some toxicity for *B. proteus*-infected meat, another experiment on similar lines was carried out.

The meat for feeding was obtained from another blown tin of corned meat with extremely offensive contents with abundant slimy growth. No anaerobes could be detected and *B. proteus* was isolated as the only organism present.

The kitten was fed on four successive days with the emulsion obtained from about 60 grms. of the putrid meat. The animal showed no symptoms of

ill health and remained perfectly well. It weighed 767 grms. at the start of the experiment and the weight did not decline at all, but steadily increased and the kitten weighed 960 grms. when killed 26 days after the first feeding.

A post-mortem examination disclosed no lesions anywhere and the animal was well nourished. Aerobic and anaerobic cultivations from the spleen, liver and heart-blood were sterile while *B. proteus* could not be isolated from the contents of the small intestine.

Exp. 11. A more comprehensive feeding experiment in which four kittens were employed. Great care was taken that all four animals received exactly the same quantities of food (mostly milk) in addition to the putrid meat emulsions. All four animals were from the same litter and were of nearly the same weight. The putrid meat used was derived from a very blown tin of corned beef with highly offensive and decomposed contents. The bacteriological examination showed the putrefactive anaerobe *B. sporogenes* in pure culture. Infected intraperitoneally in pure culture into a guinea-pig it was non-pathogenic.

The feeding emulsion, obtained as above, was all prepared at once and kept in flasks and the extract from 60 grms. of meat was used for each feeding experiment. The emulsion dose was given with milk.

Kitten A. Fed on seven consecutive days with the whole emulsion, *i.e.* bacteria and products.

Kitten B. Fed on the same seven days with the sterile filtrate from another portion, filtered through a porcelain filter.

Kitten C. Control, pure food only being given.

Kitten D. The bacteria on the porcelain filter used to filter the emulsion fed to Kitten *B* were scraped off and emulsified in sterile water, several lots of water being used. The mixed emulsions were centrifugalised, washed and recentrifugalised. The bacterial bodies in this way separated from the chemical products of decomposition were then emulsified in a little water and mixed with milk and fed to Kitten *D* on seven consecutive days.

In all cases the milk used for feeding was sweetened condensed milk. The animals were kept in separate cages. Kitten *A* remained seemingly in good health until four days after the last feeding, then appeared less lively and not in good condition. It revived somewhat and appeared better, but seven days after the last feeding showed inflammation of one eye. This became worse and later affected both eyes. The suppurative condition of the eyes increased and the animal was obviously ill. It would take but little food and became moribund and was killed 22 days after the start of the experiment.

On post-mortem the animal was found to be very thin with little or no abdominal fat. There was marked excess of fluid in the peritoneal cavity. The small intestines, stomach, kidneys, liver and other internal organs appeared healthy.

Aerobic and anaerobic cultivations from the peritoneal fluid, heart-blood, liver, and spleen were all negative except that the anaerobic growth upon egg-

meat medium from the liver yielded *B. sporogenes* identical in its characters with the strain found in the putrid meat used for the feeding.

The eye conditions were very marked, both showing severe purulent inflammation with nearly complete corneal opacity in the right eye.

Kitten *B* remained quite well and lively throughout, showing no symptoms at any time. No eye inflammation. When killed was well nourished and showed no abnormalities.

Kitten *C* remained well and lively and showed no symptoms apart from a loss in weight. This loss was not progressive but a big drop of nearly 100 grms. took place between the sixth and tenth days. It then increased fairly regularly in weight, but rapidly lost weight again (94 grms.) during the three days before death: 23 days from the onset of the experiment it was found dead although apparently in good health the day previously.

Post-mortem the animal was found to be thin, but no abnormalities were detected. Animal parasites were looked for, but nothing detected to indicate the cause of death. Cultivations from the internal organs were sterile. There were no eye symptoms or lesions.

Kitten *D* remained well and lively until 14 days after the onset of the feeding when inflammation in one eye was noticed. In a day or two this was marked and purulent and later extended to both eyes. The animal refused to take much food and became ill and was killed in a nearly moribund condition 25 days after the start of the experiment.

Post-mortem both eyes showed a very purulent condition with suppuration of the cornea. The animal was very thin with no fat in the abdominal wall or around the organs. There was no excess of fluid in the peritoneal cavity while the internal organs appeared healthy. Aerobic and anaerobic cultivations from the heart-blood were sterile but *B. coli* was isolated from both the liver and the spleen.

The weight changes in grammes were as follows:

	A	*B*	*C*	*D*
Weight at onset of the feeding	650	648	623	644
Loss of weight at end of the 7 days of feeding	99	73	13	68
Loss or gain in weight during the 14 days after the cessation of feeding	− 91	+117	−110	− 63
Loss or gain in weight at end of 21 days from start of the feeding	−190	+ 44	−123	−131

Unfortunately the inflammation of the eyes which developed in two of the kittens (*A* and *D*) deprives this experiment of most of its value, but it is included in the series as it has some special points of interest.

Towards the end of the experiment these kittens consumed very little of their milk rations and this and the severe eye conditions are sufficient to account for the loss of weight.

The loss of weight in the control kitten is unaccountable. Part of it, no doubt, was due to the insufficient food given since this animal only received exactly the same amount of food as the others and the quantity of this was

governed by the capability of the kitten which consumed least. The fact that only tinned food was given may have had something to do with it.

The bacterial filtrate evidently had no permanent prejudicial effect upon the kitten so fed (*B*).

From another point of view these eye lesions are of interest since the conditions found almost exactly correspond with the description of xerophthalmia recorded by Osborne and Mendel and by McCollum as resulting in experimental animals supplied only with a diet free from the fat-soluble *A* vitamine substance. As already mentioned the kittens were entirely fed (until after the eye lesions had developed) with condensed milk and corned beef products, neither being fresh foods. I was unaware of this condition until Professor McCollum drew my attention to it in America some months after this experiment was completed, otherwise a more detailed study of the eye conditions would have been made.

That the eye conditions were due to local infection is the more probable explanation and is supported by a further experiment with another kitten carried out some nine months later. In this experiment a young healthy kitten was fed daily with sound shop condensed milk mixed with water, some of the feedings being with sweetened others with unsweetened milk. No other food of any description was given. This diet was continued for four weeks. The weight steadily diminished and after four weeks was reduced from 987 to 932 grms. About 11 days from the onset of the experiment the animal appeared unhappy, lethargic and slow in movement, but recovered again in a few days' time. When the experiment was discontinued the kitten was normal, in good health and at no time developed any eye symptoms.

Unrestricted quantities of the condensed milk were given but the kitten did not like it and frequently would drink but little and this may have been sufficient to account for the loss of weight apart from the absence of suitable vitamines. When transferred to another diet it rapidly put on weight.

Exp. 12. An experiment upon the same lines as Exp. 11, but using a different feeding material and with some minor modifications.

The putrid food used was a mixture of four tins of canned marine products as follows:

No. 310. Crayfish. A very blown tin which, when opened, showed a decomposed mass strongly putrefactive. The condition was due to a putrefactive anaerobe (A. 465), the only living organism present. The chemical tests showed a very high amino-acid content (Sörensen figure) while a positive test for tyrosine was obtained showing that definite putrefactive substances were present.

No. 311. Crayfish. A very blown tin. The contents were strongly putrefactive, although not nearly so broken down as No. 310. No anaerobes were isolated and the bacterial cause of the decomposition was not found, having probably died out. The only organism isolated was an aerobic sporing bacillus of *B. subtilis* type. The tyrosine test was negative but the amino-acid figure was very high.

No. 312. Crab. A very blown tin. Abundant gas escape when opened with a strongly putrefactive odour, the crab meat, however, not being much broken down. Anaerobes

were absent and the only organisms isolated were a sporing aerobe of *B. subtilis* type and a non-sporing bacillus which did not produce gas. The tyrosine test was negative but the amino-acid figure was very high.

No. 313. Salmon. A very blown tin. Abundant gas, with a very offensive odour, escaped when opened. The fish was soft, broken down and indeed pulpy, with gas exudation. Here again the bacterial cause of the condition was not isolated and probably had died out, the only organisms isolated being a diplococcus and a non-sporing non-gas producing aerobe. The tyrosine figure was negative but the amino-acid figure was extremely high.

The mixture obtained from these four samples represented therefore a feeding mixture of high but varying degrees of putrefaction and containing a number of different living bacteria at least one of which was actively associated with the changes. If putrefactive material is prejudicial by feeding to kittens this mixture certainly should have exhibited to the full such harmful properties.

The portions of the four tins not required for the other examinations were emptied out and rubbed up in a mortar with five times their weight of sterile water. The emulsion was kept at 37° C. for one hour. The turbid liquid was squeezed out through fine muslin and the solid remainder again extracted with half its original weight of sterile water for a further hour at 37° C.

The liquid was re-strained through fine muslin and the residue with half its weight of water again extracted. The turbid liquids were all mixed together in a large flask. The weight of fish taken was known so it was possible to arrange that the extract from 20 grms. should be the given dose for each feeding; this amounting to 60 c.c.

The strongly putrefactive, offensive liquid was kept at room temperature and used throughout for the feeding tests.

Four young kittens were used, three being from the same litter, and they were weighed carefully every two days for a week before the experiment started.

Kitten A. Fed on seven occasions out of eight consecutive days with the whole 60 c.c. of emulsion, *i.e.* bacteria + products.

Kitten B. Fed on the same seven days with the sterile filtrate from another 60 c.c. filtered through a porcelain filter.

Kitten C. Control. Milk only being given.

Kitten D. The bacteria on the porcelain filter used in connection with Kitten *B* were scraped off into sterile water, several lots of water being used. The bacterial bodies separated from their chemical products were used for the feeding of this animal, and were fed on the same days as for the other kittens.

In this experiment great care was taken to give the kittens exactly the same amount of other food, the food used being 50 c.c. of milk for each animal. This was raised to 100 c.c. as soon as the experimental feeding was finished, while bread or fish was also added, but throughout each animal received rigidly the same quantity of food.

Kittens *A* and *B* found their food distasteful, but they would take it if no other was given. After the first two days it was found simpler to feed these two animals by means of a siphon stomach tube. They took the food very well in this way. There was no difficulty with the bacterial emulsion, Kitten *D* taking it readily when mixed with a little milk.

The kittens were allowed to mix and take exercise together after they had taken their dose as in this way they were livelier and seemed better.

Temperature records were found useless, and the tests relied upon to judge the condition of the animals were their weight, their general condition (liveliness, playfulness, appearance of coat), and finally the post-mortem changes.

The weight changes in grammes were as follows (animals weighed every two days):

	A	*B*	*C*	*D*
Wt. at onset of the feeding	810	816	728	756
Wt. at end of the 8 days of feeding ...	672	689	650	668
Wt. 3 weeks after end of experiment ...	992	1038	921	967
Loss of wt. at end of the 8 days	138	127	78	88
Gain of wt. in last 3 weeks	320	349	271	291
Total gain in wt. during the whole 29 days	182	222	192	210
Total gain in wt. during the whole 29 days per 100 grms. of body wt.	22·5	27·5	26·5	27·9

Kitten A. Considerable subcutaneous fat, abdominal wall of average thickness, considerable omentum fat and around the kidneys; would not call the animal badly nourished, but was not fat. All internal organs appeared normal. Section of small intestines showed no changes. Cultivations from spleen and liver sterile.

Kitten B. As for Kitten *A*, but rather more fat.

Kitten D. As for Kitten *A*, but rather more fat.

Both *B* and *D* were better nourished than *A*.

Not considered necessary to make a post-mortem examination of the control Kitten *C*.

Exp. 13. A repetition of Exp. 12, but with different material. The feeding mixture used was a mixture from four tins of unsound fish products as follows:

No. 334. A very blown tin of sardines. Escape of offensive smelling gas when opened, but the fish itself was very little broken down and with only a slight odour. Bacteriologically it was sterile. Chemically it gave a slight positive tyrosine test while the amino-acid figure was not above the average.

No. 335. A blown tin of salmon. When opened, marked gas escape and the fish had an offensive odour but not marked, while the salmon was not at all broken down. Sporing aerobic bacilli and a streptococcus isolated. No anaerobes isolated. No chemical examination made.

No. 336. A blown tin of salmon. When opened an abundant escape of very offensive gas, while the salmon was broken down and decomposed with a very offensive odour. An anaerobe was present but died out in the attempt to isolate it in pure culture. A streptococcus was the only other organism isolated. No chemical examination made.

Fourth tin. A tin of salmon which was blown and which showed offensive and decomposed contents was inoculated with A. 474, a putrefactive anaerobe isolated from other canned foods. The tin was resealed up and incubated for two days at 32° C. The tin became very blown and when re-opened showed very offensive and still further broken down contents. A. 474 recovered.

The last two tins were selected as examples of very advanced putrefactive changes with the presence of at least one putrefactive anaerobe. The first two tins were used as types of

much less developed putrefactive changes as it is possible that more toxic products might be present in the earlier stages.

The method of making the feeding emulsion was exactly the same as for Exp. 12. In addition, to complete the possible toxicity of the mixture, two broth cultures of two putrefactive aerobes of *B. proteus* type (A. 213 and A. 248) were added to the flask of offensive liquid.

The feeding dose was the same as Exp. 12, while four kittens were used: Kitten *A* received the whole emulsion, Kitten *B* the sterile filtrate, Kitten *D* the emulsified bacteria without the chemical products, Kitten *C* (the control) received no fish extract. The kittens were fed on seven consecutive days with the fish extracts, all the animals receiving in addition exactly the same amount of other food; milk only being given until the end of the experimental feeding, then milk and bread.

The other details were the same as for Exp. 12 except that in every case for Kittens *A* and *B* the method of feeding was by the stomach tube.

The only points noted as regards the condition of the kittens were that on July 13th and 14th (sixth and seventh feedings respectively) Kitten *B*, about a quarter of an hour after feeding, vomited about half or less of the dose and evacuated liquid from the bowel. The animal seemed ill and staggered about but recovered completely after about 20 minutes.

Kitten *A* (seventh feed) showed similar symptoms, but the vomiting was only a little, but no diarrhoea. These disturbances were probably reflex in origin and associated with the method of feeding.

The weight changes (in grammes) were as follows:

	A	*B*	*C*	*D*
Wt. at the onset of the feeding	710	761	615	683
Wt. at end of the 7 days of feeding ...	720	723	623	702
Wt. 21 days after end of the experiment ...	1010	935	891	964
Loss or gain of wt. at end of the 7 days ...	+10	−38	+8	+19
Gain of wt. in last 3 weeks	290	212	268	262
Total gain in wt. during the whole 28 days	300	174	276	281
Total gain in wt. during the whole 28 days per 100 grms. of body wt.	42·4	22·9	44·9	41·1

Kitten *B* showed some loss, instead of a progressive gain, of weight during the second week after the cessation of feeding.

The post-mortem appearances in Kitten *A* showed a well-nourished animal with a good deal of subcutaneous fat, fat round the kidneys, etc. Internal organs appeared perfectly normal.

It may also be mentioned that a guinea-pig inoculated intra-peritoneally with 1·0 c.c. of the sterile filtrate at the time of the first feeding remained perfectly well.

SUMMARY OF THE ANIMAL EXPERIMENTS.

While not completely concordant, interesting deductions can be drawn. The putrid meat extracts containing both the bacteria and their products, were fatal to two rabbits when the method of introduction was by subcutaneous

injection. A rabbit fed with the same material remained unaffected. On the other hand two rabbits and one kitten injected either subcutaneously or intraperitoneally with the chemical products freed from bacteria showed no ill effects, apart from loss of weight. Of two animals injected with the bacteria washed free from their products one, a rabbit, showed no ill effects, the other, a guinea-pig, died from *B. welchii* infection.

The feeding experiments are mostly in agreement. Exps. 11, 12 and 13 are more conveniently considered together as more complicated in design and arrangement. Apart from these six young kittens were fed on different occasions with meat from different sources but in every case in a definitely putrid condition. For four of them there were no symptoms and no maintained loss of weight although in one (Exp. 11) there was evidence of impairment of nutrition and a restricted gain in weight. In two of the experiments *B. proteus* was very abundant in the fed material.

In one of the remaining two experiments there was a definite loss in weight at one part of the experiment while even after 32 days the animal had only increased 18 grms. There were no symptoms of ill health. In the other there was a marked loss of weight followed by the death of the animal but there were no symptoms of ill health during life. In this case *B. proteus* was abundant in the feeding material.

This suggested toxicity of *B. proteus* was not in accordance with the other two feeding experiments in which this organism was abundant.

Exp. 11 was confused by the eye complications in two of the kittens but Exps. 12 and 13 are very instructive. They were carried out with great care and with every endeavour to eliminate disturbing factors. Both were fed with canned fish in various stages of decomposition. Taking into consideration the variable factors which always affect feeding experiments the results are very concordant and rather striking.

In both sets of experiments most of the eight kittens lost or put on insufficient weight during the actual period of feeding. This was less noticeable in Exp. 13 when it was possible by direct introduction of the food into the stomach to give regularly a larger food ration. The amount of this ration had to be the same for each animal and was liable to be restricted if the kittens took a long time to drink up their putrid emulsions. In Exp. 13 three out of the four showed a gain in weight during this period.

Apart from some loss of appetite all the eight kittens remained well throughout.

In Exp. 12 both kittens *A* and *B* lost considerably more weight than *C* and *D*, but after a further three weeks, *B* had caught up the others. The gain in weight, for 100 grms. body weight, of *B*, *C* and *D* at the end of the experiment is extremely close and shows clearly that given the same amount of food there was no permanent damage to *B*. Kitten *A*, fed with the whole emulsion, still lagged behind in weight. It evidently had not fully recovered the great loss of weight during the actual feeding, but that it was catching up

is shown by the fact that during the three weeks following the feeding its gain per 100 grms. of body weight was 39·3 grms. compared with 42·7, 37·2 and 38·5 for *B*, *C* and *D* respectively. In other words it was putting on weight faster than either the control or the animal fed with washed bacteria.

In Exp. 13, as for Exp. 12, the kitten *D* fed with washed bacteria, behaved exactly like the control and the two experiments show very clearly that the bacteria themselves are without harm and that any prejudicial effect can only be ascribed to the products. In Exp. 13 the three animals *A*, *C* and *D* behaved almost exactly alike, showing almost the same weight increase (8–19 grms. only) during the feeding period, while at the end of the 28 days of observation their gain per 100 grms. of body weight was extremely close. In this experiment the only animal affected was Kitten *B* which not only lost weight during the actual feeding but could not pick up in the subsequent three weeks, its weight increase per 100 grms. for this period being only 27·8 grms. compared with 40·8, 43·6 and 38·4 for *A*, *C* and *D* respectively.

This loss in weight when fed with the filtered products is clearly not a regular phenomenon since it was not observable in Exp. 12 or in Exp. 11, where the kitten feeding for animal *B* was not complicated by any eye lesions.

It must be taken into consideration that the amount of putrid material consumed was enormous, each individual dose being very large, while it was given *daily* over many days. That these heroic doses of such very nauseating substances should have produced so little disturbance of nutrition or loss of weight is striking, and strongly suggests that their toxicity is either entirely absent or of the lowest grade.

In no case (except Exp. 9) was there the slightest evidence of infection or of any ill effects, apart from disturbance of nutrition probably to be accounted for by the nauseating food.

GENERAL CONSIDERATIONS.

The problem of the prejudicial properties of decomposing food can be considered from points of view other than those of direct feeding experiments. If such food possesses the toxicity commonly ascribed to it three contributory lines of study should bring forward evidence to support the contention. It should be possible to isolate the organisms associated with this condition and to show that they are capable when fed of producing prejudicial symptoms. The bio-chemist should be able to separate the products of putrefaction and prove which of them possess disease producing properties. In the third place it should be possible to point to outbreaks of food poisoning or illness in individuals caused by the ingestion of putrid material. These contributory points merit some consideration.

Toxicity of the putrefactive bacteria. We do not know all the bacteria associated with putrefaction and it is doubtful how far it is justifiable to speak of putrefactive bacteria as if they were a separate group. Undoubtedly, however, certain organisms are found commonly associated with the putrefactive

changes in foods and are capable, singly or in combination, of producing the chemical products we associate with putrefaction. The most important of such organisms are *B. proteus* (using the term to include a group of organisms) and the putrefactive anaerobes such as *B. sporogenes* and *B. putrificus*.

The most putrefactive of these anaerobes are non-pathogenic to laboratory animals even when injected and appear to be quite harmless when fed.

The pathogenicity of *B. proteus* is higher as many strains are decidedly pathogenic on injection under the skin, but their pathogenicity by feeding is negligible or absent. With strains isolated from cases of infantile diarrhoea, Metchnikoff and his followers set up in a few instances gastro-enteritis by prolonged feeding, while Herter and Broeck caused diarrhoea with green stools in one monkey out of three fed with a strain of this organism. There is no evidence that I can find showing that strains of this organism isolated from putrefactive material are capable of setting up illness in animals by feeding. In several of the experiments recorded above, *B. proteus* was very abundant in the putrid foods used for feeding.

The study of the chemical products of putrefactive origin may be said to have passed through two phases. The first of these is the one dominated by the ptomaine hypothesis. Earlier investigators, working with a very incomplete knowledge of the decomposition products of the protein molecule, isolated a number of products of the nature of diamines from animal matter which they had allowed to putrefy for long periods and which diamines, when injected into animals, caused marked symptoms usually culminating in death. They were isolated from the late stages of putrefaction and represented late protein degradation products. They were only produced when the food was far too nasty to run any chance of being eaten. The whole of the evidence as to their toxicity rests upon *injection* experiments and there are no facts showing that they have any material toxicity when introduced by the mouth. Ptomaines can certainly be dismissed as having anything to do with the alleged toxicity of tainted meat.

The second phase is one widely accepted but while more scientific in its basis is equally unconvincing. It relies for its evidence upon the fact that certain definite protein degradation products which are of considerable toxicity are manufactured by the activities of putrefactive bacteria and that these might be produced in the early stages of putrefaction. For example it has been shown that the poisonous bases β-imidazolethylamine and tyramine are produced by the action of putrefactive bacteria upon histidine and tyrosine, two amino-acids, early stages in the breaking down of proteins. The evidence, however, as to their poisonous properties is derived from injection and not feeding experiments, while the fact that these poisonous bodies are produced from the cleavage of proteins by bacterial action in the *normal* intestine suggests that the human body possesses a defensive mechanism capable of dealing effectively with them.

There is no evidence, that I am aware of, showing that these poisonous

bodies occur to putrefactive foods and that when fed to animals they exert any poisonous action. In other words investigations upon the chemical products of putrefactive bacilli in meat or other food in a condition in which it would be eaten (the specific food poisoning bacilli are *not* putrefactive bacilli) have failed to show any substance or group of substances capable of originating symptoms of ill health when taken by the mouth[1].

As regards outbreaks of food poisoning[1] a very careful study of the literature leads to the conviction that there are no recorded outbreaks of food poisoning which have been proved to be due to the consumption of food in a putrefying condition unaccompanied by the presence of specific food poisoning bacteria or their specific toxins. Small outbreaks confined to a single case or two or three members of one family are usually not investigated so it cannot be asserted that none of these could be due to the consumption of food in an incipient state of decomposition, but certainly the connection has never been established.

A study of the evidence along these accessory lines of inquiry singularly fails to bring forward any evidence associating the consumption of food in a state of incipient putrefaction with illness in those who consume it.

In support of the argument as to the limited toxicity of putrid food we have the well-known facts that many uncivilised races habitually consume fish, game and other foods in a condition of definite putrefaction, while "civilised" man, in his preference for game which is "high," is following a practice only differing in degree.

SOME ADMINISTRATIVE AND PRACTICAL CONSIDERATIONS.

It may be advanced that a view which minimises or denies the evidence incriminating tainted meat as a cause of illness is a very damaging one administratively and will, or may, lead, if accepted, to a disregard of cleanliness and the consumption of food which is stale or possibly even tainted. It may further be contended that whether the view of the highly dangerous condition of tainted meat is right or wrong the conception has been of great advantage to the administrator and a powerful means whereby improvements have been effected in obtaining a cleaner, fresher and purer food supply.

These are important practical considerations and demand attention.

In the first place the animal experiments recorded do not suggest that food in a putrefying condition is harmless to man and can be neglected. The actual experiments show some loss of weight and disturbances of nutrition in several cases with the very large doses given, and it is not safe to assume without more evidence that the intestine of man is as little sensitive as that of kittens. The report is more particularly intended to draw attention to the absence of positive scientific data incriminating putrefactive food as a cause of definitive illness and to emphasise that this mass action of putrefactive bacteria and their

[1] These two aspects are only touched upon here. They are dealt with in considerable detail in my book, *Food Poisonings and Food Infections*, 1919, pp. 115 *et seq.*

products is a minor, if not a negligible, matter in the production of toxic symptoms in man. Harmfulness from bad food is a matter of specific infection with particular pathogenic bacteria in all or almost all cases.

In the second place if food is found to be decomposed it has evidently been exposed to conditions favouring bacterial infection and such infection may include the special bacteria associated with food infections. Confronted with decomposing food we cannot say without detailed investigation if this is the case or not, so whatever views are held it would be necessary and justifiable to condemn such food as an administrative action.

In the third place the stimulus needed for effective administrative action at the present time is a realisation that food poisoning outbreaks, and attacks of illness generally, from unsound food, are due to infection with specific bacteria in nearly all if not all cases. The present hazy conceptions as to food poisoning and its relationship to tainted food are merely hindrances to effective administrative action. Progress in the prevention of these conditions has been so slow and in the main ineffective because the fundamental importance of specific bacterial infection has neither been realised nor acted upon.

In the end I consider that the administrative control of our food supply will not only not be weakened, but greatly strengthened, by a recognition of the conceptions advanced here.

We have an exact parallel instance in regard to the hypothesis of the close and intimate association between outbreaks and cases of diphtheria with drain air and unsound drains.

This incorrect and exploded hypothesis was undoubtedly the driving cause of an enormous amount of valuable sanitary work being carried out, the broad general effect of which was the improvement of the health of the community. On the other hand, under its blighting influence it caused immeasurable harm. Case after case of diphtheria enquiry ended with the discovery of a broken drain pipe and the true cause was missed since it was never sought for, and the unrecognised infecting case or contact was left to spread the disease broadcast. I have known it advanced that the drain hypothesis, if not true, was at least very beneficial as a lever for good works and that to throw doubt upon it was not in the best interests of public health. As I have mentioned, the parallel is a close one and may be pressed in all its phases. It is the same old quarrel between the general and the specific causation of disease.