# THE MORGAN BACILLUS

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Received for publication July 5, 1933

The isolation by Morgan (1906) of a previously undescribed bacillus—"Morgan's bacillus Type I"[1]—from the stools of 28 out of 58 infants with summer diarrhea was followed by other studies[2] which were thought to indicate that this organism bears a causal relation to diarrhea in infants and young children. The causation of adult diarrhea and dysentery has also been attributed to this organism, particularly by French authors and by students of dysenteric infections during the Great War.[3] Phalen and Kilbourne (1910) considered that dysentery in the Philippines was due in part to the Morgan bacillus; this was "the only type of dysentery" encountered in certain regions. Later investigators have found the Morgan bacillus in a variety of pathological con-

[1] Several other bacillary "types" were described by Morgan, but they have not been as commonly reported by later investigators, and "Type I" has by common consent become "Morgan's bacillus," "B. Morganii," or "Salmonella morganii." "B. morgani" is used synonymously with "B. Morgan No. 1" in the 3d edition of the Catalogue of the National Collection of Type Cultures, London, 1931.

Waaler (Jour. Bact., 1931, **22**, 261) has recently reported the presence of Morgan's Type XII in five cases of infection of the urinary tract.

[2] Morgan, 1907; Morgan and Ledingham, 1908–9; Alexander, 1911–12; Lewis, 1912–13.

[3] Tribondeau and Fichet, 1916; Archibald, Hadfield, Logan and Campbell, 1916, (who observed that in a series of diarrheas connected with the advent of sandstorms "Morgan's bacillus was the only known pathogenic organism isolated"); Delille, Paisseau, and Lemaire, 1916; Thomson and Mackie, 1917 (who studied dysentery in Egypt and state that 5 out of 30 cases "very thoroughly examined" showed *B. Morgani* "present in large numbers"); Pirie, 1917 (who worked on East African dysentery—note, however, the divergent cultural characters of the African "Morgan bacilli" in the American Type Culture Collection, Nos. 973–978); Douglas and Colebrook, 1920; Rey, 1920; Besson and deLavergne, 1921; Dopter, 1921.

ditions: chronic discharging wounds (Whittingham, 1919); ulcerative colitis (Thjötta, 1920); fatal septicemia (Magath and Jackson, 1925); pyelitis (Riding, 1927); fatal cholecystitis (Thjötta, 1928); pyelitis and colitis (d'Aunoy, 1929); enteritis associated with mastoiditis in infants (Dick, Dick and Williams, 1928); and summer diarrhea in children (Mackenzie and Batt, 1930). Stewart (1928) has claimed that the Morgan bacillus is commonly present in the intestinal tracts of patients with mental disease and that its elimination from the bowel (through vaccination) is followed "by improvement in bodily health and possibly improvement of the mental condition.

On the other hand, its pathological significance, especially in gastrointestinal illness, has been questioned by several writers. Davidson (1920, 1922), who made a careful study of dysentery in Baltimore, Maryland, and Birmingham, Alabama, considers it "highly improbable that B. Morgan No. 1 is of etiological importance in diarrhea." Davidson and also Tenbroeck and Norbury (1915) point out that this bacillus does not agglutinate with the serum of patients in whose stools it is found and that it is not infrequently present in the stools of normal persons and in animals. Gardner (1929), in a recent critical summary, decides that "there is no conclusive evidence that Morgan's bacillus is the cause of intestinal disturbance or any other disease in man."

An etiological relation of Morgan's bacillus to typhoidal or paratyphoidal diseases in the United States has recently been suggested anew by the work of Havens and Ridgway (1929a, 1930) who state that "In a series of 49 cases [in Alabama], clinically resembling paratyphoid fever, *B. Morgani* was isolated from the feces in all the cases, from the blood in six cases and from the urine in 11." It was thought by Havens to be particularly significant that, while agglutination tests with other organisms were invariably negative, agglutinins for the strain recovered from each patient were present in that patient's serum in titers ranging from 1:40 up to 1:2560.

In the course of studies on gastrointestinal disease the writers have not infrequently isolated bacilli that resembled more or less closely the "*B. Morgani*" type. Notes made on these organisms, supplemented with cultural and serological tests upon strains

from type culture collections and other sources, are here recorded as a contribution to the study of this group.

The salient features of Morgan's bacillus mentioned by most writers are: (1) gas production in glucose, levulose and galactose; (2) no fermentation of lactose, sucrose, mannitol or dulcitol; (3) indol production; (4) motility usually present, sometimes absent. It is evident, however, that such characters by themselves are insufficient for purposes of present-day bacterial identification.

Examination of the published descriptions of Morgan's bacillus reveals considerable lack of uniformity and completeness. Some features may be briefly noted.

*Lactose.* Although Morgan's bacillus is characterized by practically all writers as a non-lactose-fermenter, many observers have failed to specify the period of time over which their observations have extended. Among others Fleming (1919), Tribondeau and Fichet (1916), Havens and Ridgway (1929b), Kligler (1919), Lovell (1929), and Mackenzie and Batt (1930) make no statement as to the length of time their cultures were incubated. Morgan (1906) apparently incubated his lactose cultures for three days at 37°C.; Dudgeon (1919) states that final readings were made on the fifth day and Levine (1925), in what is perhaps the most extensive comparative study of the group yet reported, states that "acid and gas formation was recorded after forty-eight hours at 37°C." Unfortunately, some writers have not made it clear whether in recording "non-fermentation of lactose" they mean the absence of gas production alone, or the absence of both acid and gas production.

The unsatisfactory nature of our knowledge about this group of organisms is further accentuated by such articles as that by Dungal (1927), who includes under the name of B. metacoli or Morgan's bacillus seven strains, all giving different fermentation reactions and all but one of which are set down as producing a small amount of gas in lactose.

The practical impossibility of correlating and evaluating imperfect descriptions of bacteria is well illustrated by the nature of the statements about the lactose-fermenting power of Morgan's bacillus. Even in those instances where the period of incubation is specified, as by Levine (1925), the observations have not, as a

rule covered a period long enough to give adequate information. It is common knowledge that in deranged conditions of the alimentary tract there are present many bacteria which are slow in fermenting lactose and often give no sign of either gas or acid production until after a week or more of incubation. Colonies of these late lactose-fermenters may be picked as "suspicious" non-lactose-fermenters from plates of Endo or eosin-methylene blue medium, and when the transplants do not show any signs of fermenting lactose over a period of several days they are frequently classed by the observer as "Morgan-like" or "paratyphoid-like" bacilli. Unless lactose tubes are kept under observation as a preliminary test for at least two weeks, a large amount of useless cultural and serological work may be expended on these late lactose fermenters.

The uncertainty about lactose fermentation shown by these facts vitiates much of the comparative work that has been done with cultures of the "Morgan bacillus." In some instances late lactose fermenters have been apparently confounded with the non-lactose-fermenting "true" Morgan bacillus.

*Sucrose.* Most descriptions of the Morgan bacillus[4] agree in stating that sucrose is not fermented. The criticism already made with respect to the time limitations on lactose fermentation applies also to sucrose. Unless an adequate period of incubation is allowed to elapse (at least fourteen days), inability to ferment sucrose cannot be regarded as established. Two of the six "Morgan" strains from the American Type Culture Collection which fermented lactose fermented sucrose also (acid in seven days); the strain from the Lister Institute Collection of "Morgan" strains which fermented lactose also fermented sucrose (acid and gas, fourteen days). Coleman (1931) isolated from a parrot a sucrose-fermenting bacillus identified as *B. Morganii.* This organism agglutinated with serum prepared from the standard Lister Institute strains When examined later by other observers (Havens and Irwin, 1932) it was not found to possess sucrose-fermenting power.

[4] Morgan, 1906, 1907; Tribondeau and Fichet, 1916; Thjötta, 1920, 1928; Mackenzie and Batt, 1930; Gardner, 1929; Havens and Ridgway, 1930; Kligler, 1919; Levine, 1925; Bergey, 1930.

*Gelatin.* All statements agree that gelatin is not liquefied by authentic strains of the Morgan bacillus.

*Indol.* There is also practically unanimity that the Morgan bacillus produces indol. Levine (1925), however, states that 2 out of his 31 strains did not form indol.

*$H_2S$ formation.* There is general agreement that sulfuretted hydrogen is produced.[5]

*Motility.* The majority of investigators state that the Morgan bacillus is actively motile; a few report it as slightly motile;[6] others state that both motile and non-motile varieties exist. The lack of uniformity of conditions under which motility is observed impairs the value of motility as a diagnostic character.

*Other carbohydrates.* Salicin: negative.[7] Sorbitol: negative.[8] Rhamnose: negative.[9] Maltose: negative;[10] positive.[11] Xylose: negative.[12] Arabinose: negative.[13] Dulcitol: negative.[14] Trehalose: negative.[15] Inositol: negative.[16] Mannitol: negative;[17] positive.[18] Galactose: positive.[19] Levulose: positive.[20] Adonitol: negative.[21] Dextrin: negative.[22] Glycerol: positive.[23] Raffinose: negative.[24]

[5] Thjötta, 1920, 1928; d'Aunoy, 1929; Levine, 1925; Bergey, 1930.
[6] Thjötta, 1920, 1928; d'Aunoy, 1929.
[7] Kligler, 1919; Levine, 1925; Bergey, 1930.
[8] Havens and Ridgway, 1929; Levine, 1925.
[9] Havens and Ridgway, 1929; Kligler, 1919; Levine, 1925.
[10] Thjötta, 1920, 1928; Mackenzie and Batt, 1930; Kligler, 1919; Levine, 1925.
[11] Besson and deLavergne, 1921; Bergey, 1930.
[12] Mackenzie and Batt, 1930; Kligler, 1919; Levine, 1925 (29−, 2+).
[13] Kligler, 1919; Levine, 1925; Bergey, 1930.
[14] Mackenzie and Batt, 1930; Gardner, 1929; Kligler, 1919; Levine, 1925.
[15] Levine, 1925 (29−, 2+).
[16] Weldin, 1927; Bergey, 1930.
[17] Thjötta, 1920, 1928; Mackenzie and Batt, 1930; Gardner, 1929; Havens and Ridgway, 1929; Kligler, 1919; Levine, 1925; Bergey, 1930.
[18] Besson and deLavergne, 1921.
[19] Besson and deLavergne, 1921; d'Aunoy, 1929; Mackenzie and Batt, 1930; Kligler, 1919; Levine, 1925 (30+, 1−); Bergey, 1930.
[20] Besson and deLavergne, 1921; d'Aunoy, 1929; Mackenzie and Batt, 1930; Kligler, 1919; Levine, 1925, Bergey, 1930.
[21] Havens and Ridgway, 1929; Levine, 1925 (30−, 1+); Bergey, 1930.
[22] Mackenzie and Batt, 1930; Weldin, 1927; Bergey, 1930.
[23] Mackenzie and Batt, 1930; Bergey, 1930.
[24] Weldin, 1927.

On the basis of published descriptions Morgan's bacillus might be briefly characterized as a Gram-negative rod, fermenting glucose, levulose and galactose with gas production; not fermenting lactose, sucrose, salicin, arabinose, dulcitol, mannitol; usually without action on xylose, trehalose, adonitol;[25] indol produced abundantly; $H_2S$ formed; gelatin not liquefied; active moti ity usually observed.

*Stock collection strains.* Cultures designated as Morgan's bacillus ("*Salmonella Morganii*," "*B. Morganii*," "*B. Morganii* No. 1") were received from the American Type Culture Collection, and from the National Collection of Type Cultures (Lister Institute); a number of recently isolated strains were also sent us by the late Dr. Leon C. Havens of the Alabama State Board of Health.

In this study we have ruled out all cultures producing acid or gas in lactose or sucrose within seven days. Six of the eight cultures (Nos. 973 to 978)[26] received from the American Type Culture Collection produced acid (in three instances with gas formation) in lactose; one of the 16 cultures (No. 2817) from the National Type Culture Collection produced acid and gas in lactose and sucrose; two of the six Havens cultures produced only acid (no gas) in glucose and two others produced acid promptly in sucrose.

The 19 cultures were submitted to further tests, as shown in table 1. Culturally, they seemed at first to constitute a homogeneous group corresponding to the characterization given above. Repeated fermentation tests, however, showed differences, especially when the period of observation continued for more than fourteen days.

One strain occasionally showed late fermentation (after fourteen days) in lactose, and four strains in sucrose;[27] acid also ap-

[25] Statements with respect to other carbohydrates than those named are contradictory or rest on the testimony of a single observer.

[26] These came originally from Pirie, South African Institute for Medical Research, Johannesburg, and were isolated by him during the War, 1916–18. Cf. Jour. Hyg., 1917, **15**, 565.

[27] Similar results have been obtained by Havens and Irwin (1932) who confirmed the writers' observation on the occasional fermentation of sucrose by several strains of the Morgan bacillus.

peared in some arabinose tubes after fourteen to twenty-one days; one strain fermented trehalose with production of acid and gas; five strains did not produce $H_2S$; seven strains produced slight acid (fourteen days) in sorbitol broth and there were some other variations.

Definite variation was shown in fermentation power by one and the same culture. Two of the strains giving slight acidity in sucrose after fourteen days were grown in nutrient broth kept at 22°C., transferred three times at two-day intervals, then plated, two colonies picked to agar slants and, after twenty-four hours growth at 37°C., again inoculated into sucrose broth. In both instances, acid appeared as early as the seventh day and there was also gas formation within fourteen days, although numerous previous tests with these strains had never shown gas production in sucrose media. In a word, the biochemical reactions of these organisms were neither uniform nor stable.

*Agglutination.* Although a number of investigators[28] have observed the presence of specific agglutinins for the Morgan bacillus in the blood of patients with diarrhea, the agglutinative action is generally limited to the strain isolated from the patient himself, other Morgan bacillus strains being little, if at all, affected. The antigenic heterogeneity of "Morgan bacillus" strains is further attested by practically all observers who have prepared specific sera by inoculating rabbits with strains from various sources.[29] Kligler (1919) found that 17 strains yielded 10 distinct antigenic types without any correlation as to source; Mackenzie and Batt (1930) found that 4 strains represented 3 antigenic types.

The 17 strains from type culture collections here studied have shown similar diversity (table 2). Since the results obtained are in complete accord with those of previous investigators[30] as

[28] Alexander, 1911–12; Thjötta, 1928; Havens and Ridgway, 1929; Magner, 1916.

[29] Alexander, 1911–12; Lewis, 1912–13; Thjötta, 1920; Mackenzie and Batt, 1930; Kligler, 1919; Dean, Adamson, Giles and Williamson, 1917; Castellani and Douglas, 1932.

[30] Coleman, (1931) for example, has recently reported the isolation of 20 cultures with the morphological and cultural characteristics of B. Morganii, none of which agglutinated with the serum prepared with a standard strain (Lister Institute). A culturally different strain (fermenting sucrose) was, however, agglutinated by the serum.

TABLE 1

| | SOURCE AND DATE OF ISOLATION | GLUCOSE | LACTOSE | SUCROSE | LEVULOSE | GALACTOSE | MANNITOL | GELATIN | INDOL | SALICIN | SORBITOL | RHAMNOSE | MALTOSE | XYLOSE | ARABINOSE | DULCITOL | $H_2S$ production | UREA | INDOL | MOTILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.T. 79 | Old type culture from Amer. Mus. Nat. Hist. Source unknown | AG[2] | – | a[14] | AG | AG[2] | – | – | + | – | – | – | – | – | a[21] | – | + | – | – | a |
| A.T. 746 | From Castellani 1918 | AG[2] | – | a[14] | AG | AG[2] | – | – | + | – | a[14] | – | – | – | – | – | + | – | – | a |
| N.C. 232 | B. Morganii No. 1 Spencer | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | + | – | – | a |
| N.C. 234 | B. Morganii No. 1 Fly | AG | – | – | AG | AG | – | – | + | – | a[14] | – | – | – | – | – | + | AG | – | a |
| N.C. 235 | Original Morgan culture summer diarrhea 1906 | AG | – | – | AG | AG | – | – | + | – | a[14] | – | – | – | – | – | + | – | – | a |
| N.C. 417 | Amer. Mus. Nat. Hist. Stool of infant. Providence, R. I. | AG | – | – | AG | AG | – | – | + | – | – | – | a[14] | – | – | – | + | – | – | a |
| N.C. 679 | B. Morganii No. 1 Morgan | AG | a[14] | a[14] | AG | AG | – | – | + | – | – | – | – | – | – | – | – | – | – | a |
| N.C. 1707 | Epidemic of diarrhea among children, Hebron, Palestine, 1923 | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | + | – | – | a |
| N.C. 1708 | | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | + | – | – | a |
| N.C. 1709 | | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | + | – | – | a |
| N.C. 2814 | Squirrel monkey. London Zool. Gardens | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | – | – | – | a |
| N.C. 2814A | Abyssinian monkey. London Zool. Gardens | AG | – | – | AG | AG | – | – | + | – | a[14] | – | – | – | a[14] | – | + | – | – | a |
| N.C. 2814B | Orang-utan | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | a[21] | – | + | – | – | a |
| N.C. 2815 | Green-billed toucan. London Zool. Gardens | AG | – | – | AG | AG | – | – | + | – | – | – | – | – | – | – | + | – | – | a |
| N.C. 2816 | False moccasin. London Zool. Gardens | AG | – | – | AG | AG | – | – | + | – | a[14] | – | a[14] | a[21] | a[14] | – | + | a[14] | – | a |
| N.C. 2818 | Pine snake. London Zool. Gardens | AG | – | – | AG | AG | – | – | + | – | a[14] | – | – | – | a[14] | – | + | – | – | a |
| N.C. 3069 | Pus—Lister Inst. 1929 "Hemolytic" | AG | – | – | AG | AG | – | – | + | – | a[14] | – | – | – | a[14] | – | + | – | – | a |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. 750 | Feces of patient with severe diarrhea, 1930 | AG | − | $a^{14}$ | AG | AG | − | − | + | − | − | − | − | − | − | − | + | − | − | a |
| H. 861 | Spinal fluid, fatal meningitis, 1932 | AG | − | − | AG | | | − | + | − | − | − | − | − | − | − | − | − | + | $a^{4}$ |
| P.R. 26 | Enteritis—suspected food poisoning | AG | − | − | AG | AG | − | − | + | − | − | − | − | − | − | − | − | − | − | a |
| P.R. 27 | Enteritis—suspected food poisoning (another case) | AG | $a^{14}$ | − | AG | AG | − | − | + | − | $a^{14}$ | − | − | − | − | − | + | − | − | a |
| P.R. 69 | Suspected typhoid | AG | $a^{14}$ | $a^{14}$ | AG | AG | − | − | + | − | − | $a^{14}$ | $a^{7}$ | $a^{21}$ | − | − | + | − | − | a |
| P.R. 77 | Diarrhea (infant of 9 months) | AG | − | − | AG | AG | − | − | + | − | − | − | − | $a^{2}$ | − | − | + | − | − | a |
| P.R. 146 | Diarrhea | AG | − | − | AG | AG | − | − | + | − | − | − | − | a | a | − | − | − | − | a |
| P.R. 171 | Enteritis—suspected food poisoning | AG | − | − | AG | AG | − | − | + | − | $a^{14}$ | − | − | − | − | − | − | − | − | a |

A.T. = American Type Culture Collection.
N.C. = National Collection of Type Cultures, Lister Institute.
H. = Strains received from the late Dr. L. C. Havens.
P.R. = Strains isolated by the writer from patients in Puerto Rice.

regards antigenic heterogeneity, it did not seem worth while to make absorption tests with specific sera. In order to determine the possible agglutinability of allied organisms by Morgan bacillus serum, 14 strains of indol-producing non-lactose-fermenting bacilli were tested with the No. 417 and No. 77 sera. All of these

TABLE 2

*Results of agglutination tests*

| TEST SUSPENSION | SERUM | |
|---|---|---|
| | PR 77 | NC 417 |
| AT 79 | | 1000 |
| AT 746 | 200 | |
| NC 232 | | |
| NC 234 | | |
| NC 235 | 100 | |
| NC 417 | | 1000 |
| NC 679 | 200 | |
| NC 1707 | | 500 |
| NC 1708 | | 500 |
| NC 1709 | | 500 |
| NC 2814 | | 500 |
| NC 2814B | | |
| NC 2815 | | |
| NC 2816 | | |
| NC 2818 | | |
| NC 3069 | | |
| Havens 750 | 500 | |
| Havens 861 | | |
| Puerto Rico 26 | 200 | |
| Puerto Rico 27 | 200 | |
| Puerto Rico 69 | | |
| Puerto Rico 77 | 1000 | |
| Puerto Rico 146 | 100 | |
| Puerto Rico 171 | 500 | |

strains produced gas in glucose broth and did not ferment lactose or sucrose, but did differ in various other fermentative characters from the typical Morgan bacillus. These strains were obtained from different sources: 3 of them were sent us from various collections under the name of Morgan bacillus; the other 11 were isolated by us from diarrheal stools. Twelve of the 14 did not

agglutinate with either Morgan serum in 1:40 dilution. The 2 remaining strains were derived from a patient with enteritis in Puerto Rico; one was agglutinated by both of the Morgan sera in 1:40 dilution, but not higher; the other was agglutinated 1:40 by the 417 serum and did not agglutinate with the 77 serum.

*Freshly isolated strains.* In the course of studies by the writers on stools obtained during outbreaks of suspected food poisoning, non-lactose fermenting indol-producing bacteria have been isolated from time to time and subjected to further study. It may be noted that all these strains of Morgan bacilli were obtained from diarrheal conditions; none were found in healthy persons or in the stools of monkeys or other animals. Six strains possessing the biochemical properties usually regarded as characteristic of the Morgan bacillus were isolated by us at the School of Tropical Medicine, Puerto Rico.[31] These 6 strains agreed culturally with the 17 strains from Type Culture Collections which have already been described; 3 of them were from feces in suspected food poisoning cases, one from a case of suspected typhoid, two from enteritis of unknown origin (one in an infant of nine months). Several of the strains, like the Type Culture strains, occasionally produced late acid (fourteen days) in lactose, sucrose, sorbitol or maltose broth (table 1).

## DISCUSSION

### *1. Differential characters of Morgan's bacillus*

Much of the current uncertainty about the significance of Morgan's bacillus is due to the incompleteness of the descriptions given by some of the observers who have reported finding this organism in pathological and normal conditions. The bacteriological details necessary for identification are completely lacking in some instances and in others are so meager that a measure of doubt must remain. Particularly with respect to lactose fermentation, many of the published descriptions are inadequate in that they do not specify the observance of a period of incubation

[31] We are indebted to Dr. E. B. McKinley, the Director of the School, for many courtesies.

long enough to determine this quality. Since many indol-producing bacteria isolated from the intestinal contents of man and other animals do not show signs of fermenting lactose within a period of one, two or three days, but do manifest active fermentation when incubated for a week or more, we are inclined to believe that these late lactose fermenters have sometimes been set down by observers as "Morgan bacilli," particularly since a number of cultures sent from the large type collections of bacteria, as well as cultures from individual investigators, have proved to be of this kind.

So far as can be determined by the published descriptions of Morgan's bacillus and by our own observations on 19 cultures identified by various investigators as Morgan's bacillus together with 6 other similar cultures isolated by us in Puerto Rico, the following characters seem to be relatively constant: a Gram-negative rod, actively motile,[32] not liquefying gelatin, producing indol abundantly, forming $H_2S$, fermenting glucose, levulose, galactose with acid and gas production, not fermenting lactose, sucrose, mannitol, salicin, sorbitol, rhamnose, maltose, xylose, arabinose, dulcitol, trehalose and inositol except that occasionally some strains after seven to fourteen days growth produce acid (never gas) from one or more of these carbohydrates. None of the 25 strains that we have examined, however, have ever produced acid from mannitol, dulcitol, inositol or salicin. All 25 strains have given a positive reaction in tartrate medium (Jordan and Harmon, 1928), resembling in this respect typhoid and colon bacilli and nearly all the other members of the intestinal group except *Salmonella paratyphi-B*.

### *2. Agglutination*

Practically all experimenters are agreed that no demonstrable antigenic unity exists within the group of Morgan bacilli. Our own results (table 2) are in accord with these observations.

[32] A number of the strains examined by us showed no motility when grown at 37°C. whereas cultures at 20° were actively motile. Some of the statements that the Morgan bacillus is non-motile may be due to the fact that only cultures grown at 37°C. were examined.

Havens and Irwin (1932) observed an antigenic change coincidental with the acquisition of sucrose fermentation, "no cross-agglutination" occurring "between the sucrose-fermenting and the nonsucrose fermenting strains from the same culture."

### *3. Occurrence and distribution*

Bacteria of the "non-lactose-fermenting" group identified by the finder as "Morgan bacilli" have been sometimes reported as present in the stools of normal persons.[33] In some instances specific identification appears to have been based on insufficient data so that it is difficult to evaluate certain of the published reports. In general, Morgan's bacillus seems to have been found more often in Great Britain (Topley and Wilson, 1929) than on the continent of Europe or in North America. Pirie (1917) reported finding Morgan's bacillus in East African dysentery, but the cultures deposited by him in the American Type Culture Collection do not resemble the standard strains of the organism. Morgan's bacillus has been reported not only in normal human beings and in patients with diarrhea or dysentery, but in the intestines of various animal species. Morgan and Ledingham (1908–9) found it in cows' feces. Lovell (1929) isolated it from a number of animals in the London Zoological Gardens (monkey, pine-snake, green-billed toucan, etc.). The cultures of the Lovell bacilli obtained from the Lister Institute Collection have mostly conformed to the standard known strains. Wilson (1927) observed a spontaneous epidemic among mice which was apparently caused by the Morgan bacillus. Flies and cockroaches caught in infested houses have been reported as harboring the Morgan bacillus.

Our own platings in Puerto Rico of 40 to 50 stools of normal adults, and in Panama of 200 to 250 stools of normal children, did not yield any "true" Morgan bacilli possessing the characters outlined in this paper, although slow lactose-fermenters were frequently found. Similarly, an examination in Panama of the

[33] Morgan and Ledingham, 1908–9; Davison, 1920, 1922; Tenbroeck and Norbury, 1915; Logan, 1914; Eyre and Minett, 1909.

feces of recently captured animals (several species of South American monkeys, opossum, armadillo, bat) did not result in the isolation of the Morgan bacillus. Platings of the stools of 29 healthy persons and 97 persons with intestinal disorders by one of us (McBroom, 1930) in Chicago did not yield any Morgan bacilli. The relatively frequent occurrence of this organism in Great Britain is of interest.

### *4. Classification*

The position of Morgan's bacillus with reference to other intestinal bacteria has been much debated. Winslow, Kligler and Rothberg (1919) express their opinion about this organism as follows: "It may perhaps represent an extreme variant of the variable *B. dysenteriae* group but we have considered it with the paratyphoids on account of its gas production." In Bergey's classification (1930) it is placed in the genus Salmonella, and Castellani and Douglas (1932) also regard it as belonging with the Salmonella type. Thjötta (1928), however, maintains that it belongs properly in the genus Escherichia or *B. coli* group and should be named *Bact. metacoli* as it was called by Danish investigators. In this opinion he is supported by d'Aunoy (1929). On the other hand, Havens and Mayfield (1930) consider that their own observations favor the Salmonella classification. In the System of Bacteriology of the Medical Research Council (Gardner, 1929) Morgan's bacillus is included in the dysentery group of bacilli among the "paradysentery" bacilli. German bacteriologists have apparently been little interested in this organism; it is given only the briefest mention in the third edition of the Handbuch der pathogenen Mikro-organismen (Kolle, Kraus and Uhlenhuth).

The active motility of all the strains we have studied, the profuse indol production and the production of gas from glucose, levulose and galactose are characters that seem to set the Morgan bacillus apart from the dysentery bacilli. The limited action on carbohydrates and the ability to form indol, on the other hand, mark it off from the Salmonellas. We are of the opinion that so far as any specific type of Morgan bacillus can be recognized to-

day it is related much more closely to the *Bact. coli* group than to either the paratyphoid or dysentery bacilli. The tendency of some strains, generally classed as Morgan bacilli, to produce acid in lactose and sucrose,[34] the occasional production of acid in other carbohydrate media, the general and abundant production of indol, the occurrence in the animal intestine and especially the existence of many independent agglutination strains all suggest relationship to *Bact. coli.*

It should be pointed out that the strains described in this paper represent a narrow and restricted choice. Many strains of organisms carried in type culture collections as Morgan bacilli and many sent to us by independent investigators, as well as a still larger number isolated by ourselves, have been more or less arbitrarily excluded from our tabulation as departing too widely from the generally accepted criteria. A large variety of such strains have been observed and seem to form a series of connecting links with the *Bact. coli* group. It is of doubtful value to bestow specific names on these organisms at the present time, especially since variations in carbohydrate fermentation and in some other characteristics are frequently observed under cultivation.[35]

The Morgan bacillus does not seem to be a sharply defined species comparable to *Salmonella enteritidis* or *S. paratyphi-B.* It bears greater resemblance to the free-living Proteus forms or to the large group of slow-lactose-fermenters ordinarily classed with *Bact. coli.* It does not give evidence of being stabilized by long parasitism in the mammalian body in any such way as the typhoid bacillus and the Shiga bacillus are stabilized. One may express some doubt as to whether a specific limitation is justified, whether there is after all any organism so definitely and consistently marked off as to deserve the designation of *Bact. Morganii.* For the present it would seem reasonable to regard these ill-defined strains as forming part of the large and variable group of bacteria which, with the Danish bacteriologists, we may call *Bact.*

[34] In addition to our own observations (table 1), see Havens and Irwin (1932) and Coleman (1931).

[35] See, for example, Coleman (1931); Havens and Irwin (1932); and this article.

*metacoli*. Their pathogenic properties seem very similar to those occasionally observed among *Bact. coli* strains, the "slow-lactose-fermenters," etc.; there is little doubt that they are occasional inciters of gastrointestinal disturbance, and of suppurative processes in various organs.

## SUMMARY

Many of the type culture strains labelled with the name of Morgan bacillus do not agree in significant cultural characters with the generally accepted criteria for this group. When widely variant strains are eliminated a certain residue of fairly uniform strains is left. Even among these there is far from being as close a correspondence as that between the strains of *Salmonella enteritidis* or of the Sonne type of dysentery bacillus. Antigenic uniformity is lacking.

Freshly isolated fecal strains with "Morgan bacillus" characteristics have, in our experience, been isolated only from persons suffering from some form of gastro-intestinal derangement.

The cultural and antigenic characters of Morgan bacilli seem to relate them nearly to *Bact. coli*. They may be reasonably regarded as an ill-defined division of the large and variable group conveniently known as *Bact. metacoli*. They possess perhaps somewhat greater pathogenic power for man than the "slow lactose fermenters" or true *Bact. coli* strains.

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