A Classification of the *Klebsiella* Group

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SUMMARY

Klebsiella strains are divided into six categories on the following reactions: fimbriation, production of gas from glucose at 37°, acid from lactose and dulcitol, methyl red test, acetoin production, citrate, urease, gluconate, malonate, lysine decarboxylase, growth in the presence of KCN and ability to produce gas from lactose at 44°. Five of the six categories are assigned specific rank, the sixth subspecific rank. The tests enable Friedländer's pneumobacillus to be distinguished from *Aerobacter aerogenes*. A new species, *Klebsiella edwardsii*, and a new subspecies, *K. edwardsii* var. *atlantae*, are named. Neotype strains of old species are proposed, holotypes of the new species and variety designated, and the catalogue numbers in the National Collection of Type Cultures and American Type Culture Collection given.

INTRODUCTION

Although the *Klebsiella* group is easily subdivided into serotypes by differences in the capsular antigens, a subdivision by biochemical tests into species is more difficult. The group comprises organisms that are non-motile, capsulate Gram-negative rods, and they have been named *Klebsiella pneumoniae*, *K. friedlaenderi*, *K. rhinoscleromatis*, *K. ozaenae* and *Bacterium lactis aerogenes* (synonym *Aerobacter aerogenes* Beijerinck). Two species, *K. rhinoscleromatis* and *K. ozaenae*, have characters that are reasonably distinctive, and the real problem is to decide whether it is possible to distinguish between *B. lactis aerogenes* and *K. pneumoniae* (*K. friedlaenderi*). This problem arises from the inadequacy of the early descriptions of these species for, as Edwards (1929) pointed out, Friedländer did not indicate whether his pneumobacillus fermented lactose or acted on milk.

Frankland, Stanley & Frew (1891) found that their strain (which they called Friedländer's pneumococcus) fermented glucose, sucrose, lactose, maltose, raffinose, dextrin and mannitol producing ethanol and acetic acid, but it did not ferment glycerol or dulcitol. Grimbert's (1895) strains fermented glycerol and dulcitol and produced lactic acid, and combining the findings of these workers Grimbert & Legros (1900) recognized two races distinguished by end-products of fermentation. However, they thought that separation into two species, *Bacterium lactis aerogenes* and Friedländer's bacillus, was unjustified, a conclusion supported by Edwards (1929).

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Duguid (1959) reopened discussion of the problem when he suggested that saprophytic *Klebsiella aerogenes* were fimbriate while pathogenic *K. pneumoniae*, *K. rhinoscleromatis* and *K. ozaenae* were non-fimbriate. This new approach seemed so hopeful that the morphological and certain biochemical reactions of 176 strains were investigated; the results are presented in this paper.

METHODS

Strains. In all, 182 strains were studied; 176 were regarded as klebsiellas as they had the following characters. Generally capsulate, Gram-negative, non-motile rods. Colonies moist and generally mucoid, not pigmented. Gelatin not liquefied. Catalase-positive; oxidase-negative. Glucose and many other sugars fermented, usually with the production of both acid and gas. Most strains fermented adonitol and inositol, and most were known to have capsular antigens of the *Klebsiella* group (Report, 1958). Included were:

- (a) Strains received from Dr E. P. Snijders, Amsterdam, as serotypes A-F (Goslings & Snijders, 1936) later redesignated 1-6 by Kauffmann (1949).
- (b) Type strains of serotypes 7-69 from Dr Ida Ørskov, Dr P. R. Edwards and Dr P. N. Edmunds.
- (c) Many strains of serotypes 1-6, and 30 strains of respiratory origin (serologically unselected) from Dr P. R. Edwards.
- (d) Strains deposited in the National Collection of Type Cultures with such names as *Bacillus lactis aerogenes*, *Bacterium aerogenes*, *B. capsulatus*, *B. pneumoniae*, *B. ozaenae* and *B. rhinoscleromatis*. Among this group of strains was NCTC 204 which in the 1st edition of the Catalogue (1922) was described as 'Probably original Friedländer strain'.

For comparison, 6 other strains with IMViC reactions -- ++ were studied: NCTC 9735, a motile strain with the capsular antigen of *Klebsiella* serotype 47.

NCTC 10,006, type strain of *Enterobacter aerogenes* Hormaeche & Edwards.

NCTC 10,005, type strain of *Enterobacter cloacae* (Jordan) Hormaeche & Edwards.

NCTC 9529, a motile, slow gelatin-liquefying strain from water; isolated at the Metropolitan Water Board Laboratory.

NCTC 9741, 9743, motile, rapid gelatin-liquefying strains, isolated by Dr E. Hormaeche from wounds.

Biochemical methods used were, in general, those recommended in Report (1958). The exceptions were as follows:

Indole: oxalic acid paper method of Holman & Gonzales (1923).

Methyl red (MR) and Voges-Proskauer (VP; acetoin): strains were grown in glucose phosphate peptone medium for 5 days at 30°. Acetoin detected by Barritt's (1936) method.

H₂S production: detected by lead acetate papers over broth containing cysteine (Clarke, 1953).

Citrate: Koser's (1923) medium was inoculated with a straight wire from a saline suspension. Positives were confirmed by subculture.

KCN: the method was that used in the Salmonella Reference Laboratory, Colindale (Dr Joan Taylor, personal communication), a modification of that described by Møller (1954).

Malonate and phenylalanine: using the combined medium of Shaw & Clarke (1955).

Decarboxylase activity: determined by Møller's (1955) and Falkow's (1958) methods but, as these sometimes differed, only the results of Møller's method are recorded here.

Other tests, not mentioned in Report (1958) were:

Fimbriae: (Duguid, Smith, Dempster & Edmunds, 1955; also called 'pili' by Brinton, 1959) observed by the electron microscope in gold-palladium shadowed films of washed, formaldehyde-fixed bacilli from broth cultures.

Adhesins: MS adhesin was demonstrated by haemagglutination tests with guinea-pig red cells with and without 0.5 % D-mannose, and MR adhesin by similar tests with tanned ox red cells (Duguid, 1959). These examinations were made on serial aerobic cultures grown in nutrient broth for 48 hr. at 37° and in a repeat series of cultures at 30°.

Capsules: demonstrated in wet India ink films of the bacilli grown in broth and on an excess-sugar agar medium at 37° (Duguid, 1951).

Gluconate oxidation: by the method of Shaw & Clarke (1955), using as control, medium without gluconate to show the absence of reducing sugar in the capsular material.

44° test: inoculated tubes of MacConkey broth were held in a water bath at 44(±0.1)° for 48 hr. Gas in Durham's tube was recorded as positive; acid without gas was recorded as negative (Report, 1955).

Fermentation v. oxidation of glucose: method of Hugh & Leifson (1953).

Serological type was that indicated by the donor, but, in addition, Dr P. R. Edwards kindly typed several previously untyped strains.

RESULTS

In addition to the group characters described under Methods the following were common to the 176 *klebsiella* strains: glucose was fermented (Hugh & Leifson, 1953) and acid was produced from xylose, arabinose, rhamnose, maltose, trehalose, mannitol, sorbitol, and salicin. H₂S was produced from a cysteine-containing medium. None digested inspissated serum. Arginine and ornithine decarboxylase activity was not found. Characters common to all strains are of no value in subdividing the group, and were not considered in sorting the results of tests.

All strains except ten were found by the India ink method to be capsulate. The division between the capsulate and the non-capsulate strains was not clear-cut. Thus, certain strains produced visible capsules on only a proportion of rods; a few were capsulate only on excess-sugar medium or produced very soft, indefinite capsules, doubtfully distinguishable from loose slime.

In sorting the characters of the 176 strains three distinct patterns were at once discernible; these corresponded to *Bacterium lactis aerogenes* (referred to as A), *Klebsiella rhinoscleromatis* (R), and *K. ozaenae* (O).

Table 1. *Frequency of reactions of 176 klebsiella strains divided into six categories*

Approximate percentages in parentheses.						
	A	Pa	Pb	Pc	R	O
No. of strains	129	7	9	5	6	20
Fimbriae	129 (100)	0	9 (100)	0	0	0
Gas from glucose	126 (97)	0	9 (100)	5 (100)	0	17 (85)
Lactose (acid) { prompt	128 (99)	0	9 (100)	0	0	2 (10)
delayed	1	7 (100)	0	5 (100)	0	18 (90)
Methyl red (MR)	13 (10)	2 (28)	9 (100)	5 (100)	6 (100)	20 (100)
Voges-Proskauer (VP)	128 (99)	7 (100)	0	2 (40)	0	0
Citrate	129 (100)	5 (71)	9 (100)	5 (100)	0	14 (70)
Urease	126 (97)	7 (100)	9 (100)	5 (100)	0	8 (40)
Glucuronate	129 (100)	7 (100)	4 (44)	2 (40)	0	0
Malonate	122 (94)	3 (43)	9 (100)	0	6 (100)	0
Lysine	127 (98)	7 (100)	9 (100)	5 (100)	0	3 (15)
44° test	71 (55)	0	0	0	0	0
Dulcitol (acid)	40 (31)	0	9 (100)	0	0	0
KCN	129 (100)	7 (100)	1 (11)	5 (100)	6 (100)	19 (95)

Strains which did not fit into these three categories were subdivided into a further three categories (Pa, Pb and Pc) on fimbriation, their ability to produce gas from glucose at 37°, on the speed of lactose fermentation, fermentation of dulcitol, methyl red test, acetoin production (VP), production of alkali in a malonate medium and growth in the presence of KCN. The use of a prototype Determinator (Cowan & Steel, 1960) was of help in sorting these strains into the different categories, and when this was done the 176 strains gave the reactions shown in Table 1.

Fimbriate strains often have adhesins and categories A and Pb could usually be distinguished from the other categories by tests for these characters. Of the 129 A strains, 120 had MR adhesin and 112 MS adhesin, whereas none of the 9 Pb strains had MR adhesin but all had MS adhesin. However, since the adhesins may vary independently and strains possessing both (as in A) may fail to show one of them in certain cultures (Duguid, 1959), they were excluded from further consideration as distinguishing tests.

A minority of the fimbriate strains were poorly fimbriate, their cultures showing not more than 5–25 % of bacilli with fimbriae; all 9 strains of category Pb were of this type. By analogy with other fimbriate bacteria (e.g. *Shigella flexneri* and *Salmonella typhi-murium*) we may expect that A or Pb might include a few non-fimbriate mutant strains, while Pa, Pc, R and O strains would in all cases be non-fimbriate (as *Shigella sonnei*). In fact, no strain with the biochemical reactions typical of A or Pb was found to be non-fimbriate, but we must accept the possibility of this.

To make a diagnostic table (Table 6) percentages shown in Table 1 were converted to symbols; below 25 % was recorded as – (negative), above 75 % as + (positive) and the intermediate percentages as *d*, to indicate that different strains gave different results. The word variable was avoided as *d* characters of the individual strains were generally stable.

Table 2. *Distribution of 176 strains among the six categories graded according to number of discrepancies*

Discrepancies	Category					
	A	Pa	Pb	Pc	R	O
None	106	7	8	5	6	12
1	18	0	1	0	0	7
2	3	0	0	0	0	1
3	2	0	0	0	0	0

The percentage values of *d* affect the worth of the diagnostic table. Since, by chance alone, many tests could be expected to give an equal number of + and – results, we can assume that a test of value (e.g. gas from glucose) will be either 100 or 0 % (or near), and that a test of no distinguishing value will be around 50 %. If we make our *d* broad (e.g. 25–75 %) our classification (and our distinguishing tests) will be firmly based, but we can expect many *d* characters, and only a few well differentiated categories. If we make the *d* range narrow, we should have fewer *d*'s and better differentiation between the categories, but unless we are prepared to accept a great many categories, a high proportion of strains would show several discrepancies.

Strains which did not fit exactly into one of the six categories we defined were

Table 3. *General characters of six klebsiella categories and the reactions of six closely related bacteria*

	A	Pa	Pb	Pc	R	O	9735	10,006	10,005	9529	9741	9743
Fimbriae	+	-	+	-	-	-	+	+	+	-	+	+
Gas from glucose	+	-	+	+	-	+	+	+	+	+	-	+
Lactose (acid)	+	(+)	+	(+)	-	(+)	+	+	+	+	-	-
Methyl red	-	<i>d</i>	+	<i>d</i>	+	+	-	-	-	-	+	+
V.P.	+	+	-	<i>d</i>	-	-	+	+	+	+	+	+
Citrate	+	<i>d</i>	+	+	-	<i>d</i>	+	+	+	+	+	-
Urease	+	+	+	+	-	<i>d</i>	+	+	-	-	+	+
Gluconate	+	+	<i>d</i>	+	-	-	+	+	+	+	+	-
Malonate	+	<i>d</i>	+	-	+	-	+	+	+	+	-	+
Lysine	+	+	+	+	-	-	+	+	+	+	+	+
Arginine	-	-	-	-	-	-	-	-	+	+	-	-
Ornithine	-	-	-	-	-	-	-	-	+	-	-	-
44° test	<i>d</i>	-	-	-	-	-	-	-	-	-	-	-
Dulcitol (acid)	<i>d</i>	-	+	-	-	-	-	-	-	+	+	+
KCN	+	+	-	+	+	+	+	+	+	(+)	+	+
Gelatin	-	-	-	-	-	-	-	-	+	+	+	+
Motility	-	-	-	-	-	-	+	+	+	+	+	+
Differences from A	0	3	3	4	9	7	3	3	6	6	7	6

* The arginine dihydrolase system takes part in this reaction (Møller, 1955). (+) = delayed; *d* = some strains +, some -.

put into the nearest and the number of discrepancies recorded. When a character was described as *d* it could not contribute to the discrepancies shown by a strain. From this sorting the results shown in Table 2 were obtained. Eight indole-producing strains had all other characters typical of category A, and they were included in the 129 strains. From Table 2 it will be seen that the most of our 176 *klebsiella* strains fitted into the categories without showing more than one discrepancy; four had two, and two had three discrepancies.

Table 3 shows the reaction of the six closely related enterobacteria in the same distinguishing tests, and it also shows the reactions (arginine and ornithine decarboxylases, motility and gelatin liquefaction) which exclude them from the *Klebsiella* group. NCTC 10006, the type strain of *Enterobacter aerogenes* Hormaeche & Edwards, has the same characters as NCTC 9735, but the latter is of additional interest in possessing the capsular antigen of *Klebsiella* serotype 47. Both these strains differ from our A category in only three characters, and show a closer relation than the other four strains to the *Klebsiella* group.

Table 4. *Correlation of strain source with category*

Category	Source		
	Respiratory	Non-respiratory	Unknown
A	59	61	9
Pa	4	1	2
Pb	4	1	4
Pc	4	0	1
R	6	0	0
O	13	0	7
Totals	90	63	23

Table 5. *Correlation between fimbriation, serotype and category*

Category	Fimbriae	Serotypes
A	+	1, 2, 4-69
Pa	-	1, 2
Pb	+	3
Pc	-	1
R	-	3
O	-	4, 5, 6

Correlation of the sources of the strains with the six categories was made when this was possible, but the sources of some strains remained unknown even after Dr P. R. Edwards had searched his records for us. One of our main interests in this investigation was to try to pick out Friedländer's bacillus from the non-respiratory organisms that were culturally similar; we described sources, therefore, under these three simple headings: respiratory, non-respiratory and unknown. Table 4 shows the relations between source and our categories.

Duguid (1959) suggested a correlation between fimbriation and serotype and, since the serotype of most of the strains was known, it was possible to see that there was a correlation between our categories and these features (Table 5).

DISCUSSION

Most workers have maintained that it was not possible to distinguish between the saprophytic *Bacterium lactis aerogenes* Escherich (syn. *Aerobacter aerogenes* Beijerinck) and Friedländer's pneumobacillus, but Duguid's (1959) suggestion that this might be possible made us review the characters of these organisms in the light of recent advances in bacterial characterization. Thus by studying the morphological features revealed by electron microscopy and combining this with the results of certain biochemical tests we have been able to divide our klebsiella strains into six categories. Differences between the categories depend on combinations of different characters, not all of which will vary in the same way in the same strain. Thus, A and Pb have only three completely different characters (KCN, methyl red and VP) but the *d* character dulcitol in A is a + character in Pb; similarly gluconate is + in A and *d* in Pb and it is unlikely that a strain would show the less typical reaction in both characters.

Pa and Pc have only one absolute distinguishing character (the ability to produce gas from glucose at 37°) but *d* occurs in five positions in the Table 6 distinguishing characters. In practice it is not difficult to distinguish between these categories, and the five strains in Pc do not fit Pa at all well. Pc has several features in common with O but, again, in practice there is no difficulty in distinguishing the categories.

A point we have not stressed, because the information is not usually available, is that the different categories are mainly made up of different serotypes; thus while A has representatives of all known serotypes except type 3, our Pb strains are exclusively of serotype 3 with one non-capsulate (and therefore untypable) strain, our Pa strains all of types 1 or 2, and our Pc strains all of type 1. It is of course possible that had more strains of the higher serotypes been examined some might have been found to belong to biochemical categories other than A.

Strains of category O show more individual differences than those of the other categories, and four strains of serotype 4 failed to reduce nitrate. Our results, taken in conjunction with those obtained by Dubay (1959), who examined 150 strains of *Klebsiella ozaenae* of serotype 4, suggest that this category might be divisible into two subcategories. Serotype 4 strains are usually urease-negative, whilst O strains of serotypes 5 and 6 are often positive in this character.

This classification of the Klebsiella group is applicable whatever taxonomic rank the group may be assigned. In schemes where the group is given generic rank our categories will be species; if the group is regarded as a species, our categories will be subspecies. In the discussion of nomenclature which follows, and in the selection and designation of nomenclatural types, the Klebsiella group is regarded as a genus.

In collecting strains we excluded from our Klebsiella group all motile strains; these are better regarded as belonging to *Enterobacter* (Hormaeche & Edwards, 1960), *Serratia* or *Hafnia*. Neither did we include any gelatin-liquefying strains. We agree with Lautrop (1956) that the so-called *Klebsiella oxytocolum* would be better removed from the Klebsiella group.

NCTC 204 is reputed to be one of Friedländer's strains; it is now non-capsulate and thus is not fully representative of the species *Klebsiella pneumoniae*. It belongs to category Pb, which can therefore be considered to represent that species. Whilst

NCTC 204 cannot be typed on the basis of its capsular antigen, Kauffmann (1949) found it to belong to O group 1; NCTC 5056 (also in our category Pb) belonged to this O group but other strains of capsule type 3 (in our category R) belonged to O group 2A. The designation of category Pb as *K. pneumoniae* is in line with the thinking of Henriksen (1952) who thought that dulcitol-fermentation was a character of the species. [Since NCTC 204 is non-capsulate, we propose another strain CDC 298/53 (NCTC 9633, ATCC 13,883) as neotype of the species *Klebsiella pneumoniae* Trevisan.

With the type species characterized, we next turn to the identification of the other categories. A is made up of organisms that would be accepted the world over as *Aerobacter aerogenes* Beijerinck. An unexpected finding was that about 50% of the strains produced gas from MacConkey broth at 44°. These 44°-positive IMViC — — + + strains are widely distributed, and have been named the 'yarn organism' (Mackenzie, Taylor & Gilbert, 1948); they correspond to Irregular type VI of Report (1935). Perhaps they are worthy of subspecific status, but this we would not propose without further study.

The binomial *Klebsiella aerogenes* was proposed and must be ascribed to a Subcommittee of the Society for Applied Bacteriology (Report, 1956). A type culture was not designed by the Subcommittee, and we have chosen and propose as neotype strain C37 isolated at the Metropolitan Water Board Laboratories from water (NCTC 8172, ATCC 13,882); this strain is 44°-negative.

Category O is *Klebsiella ozaenae* (Abel) Bergey *et al.* As this category is biochemically less homogeneous than the others, we do not at present feel justified in selecting a neotype culture. Further study of a larger number of strains may show that division into two varieties is desirable.

Category R is *Klebsiella rhinoscleromatis* Trevisan. We propose strain R 70 (NCTC 5046, ATCC 13,884) as the neotype culture.

We are left with the two categories Pa and Pc; these have many characters in common and we regard them as two varieties of one species. It is not possible to assign to them a specific epithet from the past, and Pa we name *Klebsiella edwardsii* after P. R. Edwards of Atlanta, who has done so much to establish the serological classification of klebsiellas. Since we are also making a variety of the species, the name becomes *K. edwardsii* var. *edwardsii* and we designate strain F1 (NCTC 5054, ATCC 13,886) as type strain. Pc becomes the second variety which we name *K. edwardsii* var. *atlantae* designating strain CDC 4610-53 (NCTC 9496, ATCC 13,887) as type strain.

Descriptions of the neotype and holotype strains are given in the Appendix.

The classification makes use of fimbriation, a character that can be detected directly only by those with access to an electron microscope. Alternatively, an almost certain indication of the presence or absence of fimbriae may be gained by testing 37° and 30° broth cultures for haemagglutination of guinea-pig red cells (MS adhesin) and tanned ox red cells (MR adhesin). However, the determination of this character is not essential for the identification of the species and subspecies defined, though all relevant information is helpful, and the more characters that are known, the clearer the identification becomes. Only those characters necessary for the differentiation of the species are included in the table for use in the Determinator (Table 6).

Any new scheme of classification should be compared with the old; our scheme supplements rather than replaces those based on serology (Julianelle, 1926; Kauffmann, 1949; Brooke, 1951; Edwards & Fife, 1952; Edmunds, 1954; Ørskov, 1954, 1955). It provides a means of characterizing species within the genus and, we hope, will help to bring classification of the Enterobacteriaceae into line with other groups of bacteria in which genera are split into species which in turn are subdivided into serotypes or other subspecific taxa.

Table 6. *Distinguishing characters of six categories*

Table for use in Determinator (Cowan & Steel, 1960).

	A	Pa	Pb	Pc	R	O
Fimbriae	+	—	+	—	—	—
Gas from glucose	+	—	+	+	—	+
Lactose (acid)	+	(+)	+	(+)	—	(+)
Methyl red	—	<i>d</i>	+	+	+	+
VP	+	+	—	<i>d</i>	—	—
Citrate	+	<i>d</i>	+	+	—	<i>d</i>
Urease	+	+	+	+	—	<i>d</i>
Gluconate	+	+	<i>d</i>	<i>d</i>	—	—
Malonate	+	<i>d</i>	+	—	+	—
Lysine decarboxylase	+	+	+	+	—	—
44° test	<i>d</i>	—	—	—	—	—
Dulcitol (acid)	<i>d</i>	—	+	—	—	—
KCN	+	+	—	+	+	+

A = *Klebsiella aerogenes* (Beijerinck) Subcom. Soc. Appl. Bact.; Pa = *K. edwardsii* var. *edwardsii* n.sp.; Pb = *K. pneumoniae* Trevisan; Pc = *K. edwardsii* var. *atlantae* subsp.n.; R = *K. rhinoscleromatis* Trevisan; O = *K. ozaenae* (Abel) Bergey *et al.*; (+) = delayed; *d* = some strains +, some —.

Table 7. *Characters of proposed neotype and designated holotype cultures*

	<i>Klebsiella aerogenes</i>	<i>K. pneumoniae</i>	<i>K. rhinoscleromatis</i>	<i>K. edwardsii</i> var. <i>edwardsii</i>	<i>K. edwardsii</i> var. <i>atlantae</i>
NCTC number	8,172 ×	9,633 ×	5,046	5,054	9,496
ATCC number	13,882	13,883	13,884	13,886	13,887
Serotype	64	3	3	1	1
Gas from glucose at 37°	+	+	—	—	+
Acid from lactose	+	+	—	(+)	(+)
Acid from starch	+	+	—	(+)	+
Acid from glycerol	+	+	(+)	+	(+)
Acid from dulcitol	—	+	—	—	—
Methyl red	—	+	+	+	+
VP	+	—	—	+	+
Gluconate	+	—	—	+	+
Malonate	+	+	+	+	—
Urease	+	+	—	+	+
Lysine decarboxylase	+	+	—	+	+
Growth in KCN medium	+	—	+	+	+
Growth in Koser's citrate	+	+	—	+	+
Simmons' citrate	+	+	—	+	+
Christensen's citrate	+	+	+	+	+
Fimbriae	+	+	—	—	—
MR adhesin	+	—	—	—	—
MS adhesin	+	+	—	—	—

Key to carbohydrate fermentation: + = positive in 1–2 days; (+) = positive in 3–14 days.

We wish to thank all those who sent us strains and especially Dr P. R. Edwards who serotyped for us many of our untyped strains.

APPENDIX

DESCRIPTIONS OF PROPOSED NEOTYPE AND DESIGNATED HOLOTYPE CULTURES

Common characters

Non-motile, non-pigmented, capsulate Gram-negative rods. Grow readily on ordinary media. Aerobic, facultatively anaerobic. Catalase-positive, oxidase-negative. Gelatin not liquefied. Indole not formed. Nitrate reduced to nitrite. Hydrogen sulphide produced from cysteine-containing medium. Phenylalanine deaminase and arginine and ornithine decarboxylases absent. Starch not hydrolysed. No gas from MacConkey broth at 44°. Acid from glucose fermentatively. Acid from arabinose, xylose, rhamnose, galactose, mannose, maltose, sucrose, trehalose, adonitol, mannitol, sorbitol, inositol and salicin.

Distinguishing characters are shown in Table 7.

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