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Compilation of small ribosomal subunit RNA structures

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ABSTRACT

The database on small ribosomal subunit RNA structure contained 1804 nucleotide sequences on April 23, 1993. This number comprises 365 eukaryotic, 65 archaeal, 1260 bacterial, 30 plastidial, and 84 mitochondrial sequences. These are stored in the form of an alignment in order to facilitate the use of the database as input for comparative studies on higher-order structure and for reconstruction of phylogenetic trees. The elements of the postulated secondary structure for each molecule are indicated by special symbols. The database is available on-line directly from the authors by ftp and can also be obtained from the EMBL nucleotide sequence library by electronic mail, ftp, and on CD ROM disk.

CONTENTS OF THE DATABASE

The database on small ribosomal subunit RNA (further abbreviated as SSU rRNA) currently contains 1804 nucleotide sequences, stored in the form of an alignment and containing the postulated secondary structure pattern in encoded form. This number comprises 365 eukaryotic cytoplasmic, 65 archaeal, 1260 bacterial, 30 plastidial, and 84 mitochondrial SSU rRNAs. Partial sequences are included if the combined length of the sequenced segments corresponds to homologous segments in *Escherichia coli* SSU rRNA amounting to at least 70% of the chain length of the latter molecule.

Previous compilations (1–5) included a table listing for each entry the species name, further specifications such as the strain, variety, or tissue used for isolation of the gene, taxonomic position of the species, length and completeness of the sequence, and accession number in nucleotide sequence libraries. Complete literature references were also included for each entry. Because the number of available structures has nearly doubled since publication of the preceding compilation (5), such a table and the accompanying references would now require an estimated 20 pages just to cover the additional structures entered in the database during the last year. Table 1 has therefore been restricted to a list of the names of species for which the SSU rRNA structure is recorded in the database. However, this list covers all the structures now filed, not just those added since the preceding compilation. Instructions for obtaining the complete table including further specifications and literature references, separately or together with the structural data, are given below.

TAXONOMIC CLASSIFICATION OF SPECIES

For the Eukarya, the taxonomic classification of the species listed in Table 1 is according to Brusca and Brusca (6) for the Animalia, according to Cronquist (7) for the higher plants, according to Ainsworth et al. (8) for the higher fungi, and according to Corliss (9) for the remaining eukaryotes.

For the Bacteria and the Archaea, the classification followed is based on the phylogeny described by Woese and coworkers (10–12). However, the assignment of a species to one of the taxa distinguished by these authors is often problematic. To our knowledge there does not exist a list assigning each bacterial or archaeal species to one of the divisions or subdivisions that they distinguish. Moreover, many sequences now become available through deposition in one of the nucleotide sequence libraries, which in many cases is not (yet) accompanied by publication in a journal. The bacterial and archaeal SSU rRNA sequences deposited in these libraries are accompanied by a taxonomic description which does not correspond to that of Woese et al. (10–12) but is based on Bergey's Manual of Systematic Bacteriology (13). Even the sequences described in the literature are not always accompanied by an assignment of the species to one of the taxa distinguished by Woese and coworkers. In order to obtain a more or less consistent classification, we have therefore constructed an evolutionary tree from the alignment of all archaeal, bacterial, and plastidial SSU rRNA sequences, 1355 in total. The method followed for constructing the tree has been described in detail elsewhere (14). In short, a dissimilarity matrix was computed, corrected for multiple mutation (15), and a tree derived by neighbour-joining (16). The outline of the resulting tree is shown in Fig. 1. Most of the clusters visible in the tree correspond to the archaeal and bacterial divisions and subdivisions distinguished by Woese and coworkers (10–12). However, in the bacterial subtree, the genera *Fibrobacter* and *Fusobacterium* do not integrate in any of the clusters. They are therefore listed separately in Table 1.

It should be noted that the evolutionary distances between the branching points leading to the clusters visible in the tree of Fig. 1 are very small, especially for the major clusters of the Bacteria. Trees such as this one were constructed periodically as the SSU rRNA sequence alignment grew in size. Although the clusters indicated in Fig. 1 were reproducibly formed, the branching order of these clusters was not constant but changed as a function of the composition of the sequence collection. However, the tree can serve to assign bacterial species to a given division or subdivision because, although the relative position of the clusters

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is variable, the appurtenance of each bacterial species to a particular cluster is stable.

In Table 1, for the Bacteria, no hierarchical distinction is made between divisions (e.g. the spirochetes) and subdivisions (e.g. the α , β , γ , δ , and ϵ subdivisions of the division Proteobacteria). This is because the subdivisions do not always form together a monophyletic cluster. As an example, in the tree of Fig. 1, the Proteobacteria ϵ group is separated from the monophyletic cluster formed by the Proteobacteria α , β , γ and δ groups. As for the division of Gram positive bacteria and relatives, its two subdivisions of high and low GC contents almost never form together a monophyletic cluster in the trees that we obtain. For the Archaea, on the contrary, a distinction is made between the divisions Crenarchaeota and Euryarchaeota (12). The latter division is subdivided into 8 subdivisions. Of these, the Methanobacteriales, Methanococcales, Thermococcales and Methanopyrales correspond to lineages distinguished by Olsen and Woese (12). The Methanomicrobiales group of the latter authors comprises the Methanomicrobium group, the Halobacteria, and *Archaeoglobus fulgidus* in the tree of Fig. 1.

SECONDARY STRUCTURE MODEL

Prokaryotic and eukaryotic models, nucleotide variability

Fig. 2 shows the prokaryotic secondary structure model, applicable to SSU rRNAs from archaea, bacteria, plastids, and mitochondria. The model of Fig. 3 applies to eukaryotic cytoplasmic SSU rRNAs. In contrast to the corresponding figures in the preceding compilation (5), the models shown in Fig. 2 and 3 do not simply distinguish between conserved and variable areas, but give a more detailed description of the variability of each site. The latter is defined as the ratio of the substitution rate at the considered site to the average substitution rate for the entire molecule. The quantitative derivation of the variability of each site from the sequence alignment is described in detail elsewhere (17). Sites that are absolutely conserved, and those that are occupied only in a limited number of SSU rRNAs, are indicated by special symbols. The remaining ones were partitioned into five equally large categories of increasing variability. In Fig. 2 and 3, such sites are represented by dots with a diameter commensurate with their variability. Variable areas previously distinguished on a more intuitive basis and indicated on the general secondary structure models of the preceding compilation (5) are still shown on Fig. 2 and 3 as V1 to V9.

Helix numbering system and changes made to the models

Helices are given a different number if separated by a multibranching loop (e.g. helices 9 and 10), by a pseudoknot loop (e.g. helices 1 and 2), or by a single stranded area that does not form a loop (e.g. helices 2 and 32). A single number is attributed to 50 'universal' helices, which are present in all hitherto known SSU rRNAs from Archaea, Bacteria and plastids. They are also present in all known eukaryotic SSU rRNAs except in those of Microsporidia, where some of these helices are missing. The number of universal helices has risen from 48 in the preceding compilation (5) to 50 because the tertiary interaction described by Woese and Gutell (18) has been taken into account. This interaction effectively transforms the helix previously numbered 19 into three helices now numbered 19 to 21.

Helices specific to the prokaryotic model (Fig. 2) are given composite numbers of the form Pa-b, where a is the number of

the preceding universal helix and b sequentially numbers all helices inserted between universal helices a and a+1. Helices specific to the eukaryotic model (Fig. 3) are similarly numbered Ea-b. In Figs. 2 and 3, not all eukaryote- and prokaryote-specific helices that are encountered in various species are indicated, because these models in fact have the shape of the *Escherichia coli* and *Saccharomyces cerevisiae* SSU rRNA secondary structure models, respectively. As an example, in *Drosophila melanogaster* SSU rRNA, the loop separating helices E23-2 and E23-5 is a multifurcation bearing two more helices numbered E23-3 and E23-4 (5). These and other supernumerary helices that are present in a minority of SSU rRNAs are not indicated in Figs. 2 and 3, one of the reasons being that the variability of the sites composing such helices cannot be computed in a dependable manner. However, in Table 2 the presence or absence of eukaryote specific helices in SSU rRNAs of different taxa is summarized.

Mitochondrial SSU rRNAs, though they can be described by the prokaryotic model, show extreme variability in length, ranging from about 600 nucleotides in flagellates to about 2000 nucleotides in plants. This coincides with the absence of several universal helices in the smaller molecules and with the presence of extra helices of the P-series in the larger ones. A tentative helix occupancy table for mitochondrial SSU rRNAs and examples of secondary structure models can be found in a previous compilation (4). The alignment of, and transposition of secondary structure models to, mitochondrial SSU rRNAs is less dependable than for other SSU rRNAs, not only because of the variability in length, but also because some of the mitochondrial sequences are very monotonous due to their high AU contents.

Examples of secondary structure models

Figs. 4 to 7 are examples of secondary structure models applied to specific SSU rRNA sequences. Fig. 4 represents the SSU rRNA of the bacterium *Escherichia coli*, whereas the SSU rRNA of the halophilic archaeobacterium *Halobacterium halobium* is shown in Fig. 5. The eukarya are represented by the structure of SSU rRNAs of the red alga *Palmaria palmata* in Fig. 6, and of the polymastigote *Giardia duodenalis* in Fig. 7. The latter model is shown as an example of a molecule possessing a restricted number of helices in variable areas V2 (helices 9 to 11) and V4 (helices E23-n). Finally, an example of a model for an animal mitochondrial SSU rRNA is shown in Fig. 8.

COMPLETENESS, ACCURACY, AND AVAILABILITY OF THE DATA

SSU rRNA sequences deposited in the GenBank and EMBL nucleotide sequence libraries are obtained weekly from the EMBL file server by electronic mail. By means of an appropriate set of programs, each new sequence is aligned with the most closely related one already present in the alignment, the secondary structure pattern is transposed to the newly aligned sequence, and the complementarity of the postulated secondary structure elements is checked. Manual corrections are made if necessary by means of a specially developed editor. Finally, the newly aligned sequence is automatically compared with the original record in order to eliminate any errors that might have been introduced during editing of the alignment.

Files containing all the SSU rRNA sequences present in our database are available in the following three formats.

- 1) The sequences, listed one by one, written continuously without the gaps needed for alignment and without indication of secondary structure elements.
- 2) The sequences, listed one by one, but with nucleotide symbols interspersed with the gaps necessary for alignment. In this file, each sequence covers 4807 positions, which is the present length of the complete alignment of all eukaryotic, archaeal, bacterial, and organellar sequences.
- 3) The sequences, listed in the form of an alignment with indication of the secondary elements. The alignment is divided into 49 pages each comprising 100 positions containing a nucleotide or a gap. These positions alternate with an equal number of positions that are either blank or contain a symbol indicating the beginning or end of a secondary structure element. The secondary structure model adopted for each SSU rRNA sequence is completely defined in this file.

In addition, there are files containing a taxonomic list of species for which the SSU rRNA sequence is known, plus further data as listed in Table 1 of the previous compilation (5) and literature references, and a file containing general documentation on the database.

These files will be made available through 'anonymous ftp' on host uiam3.uia.ac.be (143.169.8.1). The files, as well as later updates, will also be made available to the EMBL nucleotide sequence library at Heidelberg for distribution on their file server and on their CD-ROM disk. Due to the increasing volume of the database, copying it onto diskettes is getting cumbersome. However, researchers who do not have access to the aforementioned distribution channels can address requests for obtaining specific parts of the database on magnetic media to the authors in writing or by sending an electronic mail message to dwachter@reks.uia.ac.be or to rrna@reks.uia.ac.be.

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Table 1. List of species for which the SSU rRNA structure is recorded in the database^a.

EUKARYA

ANIMALIA

CHORDATA

VERTEBRATA

MAMMALIA

Homo sapiens 1
Homo sapiens 2
Homo sapiens 3
Mus musculus
Oryctolagus cuniculus
Rattus norvegicus 1
Rattus norvegicus 2

AVES

Gallus gallus
Turdus migratorius

REPTILIA

Alligator mississippiensis
Heterodon platyrhinos
Pseudemys scripta
Sceloporus undulatus

AMPHIBIA

Ambystoma mexicanum
Amphiuma tridactylum
Bufo valliceps

Discoglossus pictus

Eleutherodactylus cuneatus

Gastrophyne carolinensis

Grandisonia alternans

Hyla cinerea

Ichthyophis bannanicus

Nesomantis thomasseti

Plethodon yonhalossee

Scaphiopus holbrookii

Siren intermedia

Typhlonectes natans

Xenopus borealis

Xenopus laevis

OSTEICHTHYES

Fundulus heteroclitus

Latimeria chalumnae

Sebastes altivelis

CHONDRICHTHYES

Echinorhinus cookei

Rhinobatos lentiginosus

Squalus acanthias

AGNATHA

Eptatretus stouti

Lampetra aepyptera

Table 1. *continued*

Myxine glutinosa Petromyzon marinus	CNIDARIA ANTHOZOA Anemonia sulcata
UROCHORDATA Herdmania momus Styela plicata	PLANTAE MAGNOLIOPHYTA LILIOPSIDA Oryza sativa Zea mays
CEPHALOCHORDATA Branchiostoma floridae	MAGNOLIOPSIDA Alnus glutinosa Arabidopsis thaliana Buckleya distichophylla Buxus sempervirens Clematis rehderiana Cornus florida Cornus racemosa Dendrophthora domingensis Euonymus alatus Fragaria ananassa Glycine max Hedera helix Hydrocotyle sibthorpioides Lycopersicon esculentum Macadamia ternifolia Nyssa sylvatica Phoradendron serotinum Schoepfia arenaria Sinapis alba 1 Sinapis alba 2
CHAETOGNATHA Sagitta elegans	PINOPHYTA CYCADOPSIDA Podocarpus falcatus Podocarpus henkellii Zamia pumila
ARTHROPODA INSECTA Acyrtosiphon pisum Aedes albopictus Drosophila melanogaster Tenebrio molitor	FUNGI ZYGOMYCOTINA Endogone pisiformis Gigaspora margarita Glomus intraradices Mucor racemosus
CHELICERATA Amblyomma americanum Eurypelma californica	ASCOMYCOTINA HEMIASCOMYCETES Candida albicans 1 Candida albicans 2 Candida glabrata 1 Candida glabrata 2 Candida parapsilosis Candida tropicalis 1 Candida tropicalis 2 Candida viswanathii Clavispora lusitaniae 1 Clavispora lusitaniae 2 Debaryomyces hansenii 1 Debaryomyces hansenii 2 Dekkera bruxellensis Dipodascus albidus Endomyces fibuliger Galactomyces geotrichum Hanseniaspora uvarum Issatchenkia orientalis 1 Issatchenkia orientalis 2 Kluyveromyces lactis 1 Kluyveromyces lactis 2 Kluyveromyces polysporus Metschnikowia bicuspidata Pichia angusta Pichia anomala Pichia membranaefaciens Saccharomyces cerevisiae Saccharomyces ludwigii
MALACOSTRACA Argulus nobilis Artemia salina Callinectes sapidus Oedignathus inermis Palaeomonetes kadiakensis Penaeus aztecus Procambarus leonensis Raninoides louisianensis Stenopus hispidus	
PENTASTOMIDA Porocephalus crotali	
NEMATODA SECERNENTEA Caenorhabditis elegans Haemonchus contortus Haemonchus placei Haemonchus similis Strongyloides stercoralis	
PLATYHELMINTHES TREMATODA Opisthorchis viverrini Schistosoma haematobium Schistosoma japonicum Schistosoma mansoni 1 Schistosoma mansoni 2 Schistosoma spindale	
TURBELLARIA Bothrosostoma personatum Crenobia alpina Dendrocoelum lacteum Dugesia mediterranea	
MOLLUSCA BIVALVIA Crassostrea virginica Placopecten magellanicus	
GASTROPODA Limicolaria kambeul	
POLYPLACOPHORA Acanthopleura japonica	
ACANTHOCEPHALA ARCHIACANTHOCEPHALA Molinitiformis molinitiformis	

Saccharomycopsis capsularis
 Torulaspora delbrueckii
 Waltomyces lipofer
 Yamadazyma guilliermondii
 Yarrowia lipolytica
 Zygosaccharomyces rouxii

EUASCOMYCETES

Ascosphaera apis 1
 Ascosphaera apis 2
 Aspergillus fumigatus 1
 Aspergillus fumigatus 2
 Aspergillus fumigatus 3
 Aureobasidium pullulans
 Byssosclamyces nivea
 Chaetomium elatum
 Coccidioides immitis 1
 Coccidioides immitis 2
 Emmonsia capsulata
 Eremascus albus
 Exophiala dermatidis 1
 Exophiala dermatidis 2
 Exophiala dermatidis 3
 Glomerella cingulata
 Hypomyces chrysospermus
 Leucostoma persoonii
 Monascus purpureus
 Neurospora crassa
 Ophiostoma schenckii
 Ophiostoma stenoceras
 Ophiostoma ulmi
 Penicillium notatum
 Podospora anserina
 Pseudallescheria boydii
 Sclerotinia sclerotiorum
 Sordaria fimicola
 Talaromyces flavus
 Taphrina deformans
 Thermoascus crustaceus
 Trichophyton rubrum

UNCERTAIN AFFILIATION

Pneumocystis carinii
 Schizosaccharomyces pombe 1
 Schizosaccharomyces pombe 2

BASIDIOMYCOTINA

USTOMYCETES

Leucosporidium scottii
 Rhodosporidium toruloides 1
 Rhodosporidium toruloides 2
 Sporobolomyces roseus
 Ustilago maydis

TRUE BASIDIOMYCETES

Athelia bombacina
 Boletus satanas
 Bulleromyces albus
 Coprinus cinereus
 Cronartium ribicola
 Filobasidiella neoformans 1
 Filobasidiella neoformans 2
 Filobasidiella neoformans 3
 Microascus cirrosus
 Spongipellis unicolor
 Thanatephorus praticola
 Trichosporon cutaneum
 Xerocomus chrysenteron

PROTISTA

ASSEMBLAGE CHLOROBIONTS

CHLOROPHYTA

Ankistrodesmus stipitatus
 Asteromonas gracilis
 Characium hindakii
 Characium perforatum
 Characium saccatum

Characium vacuolatum
 Chlamydomonas reinhardtii
 Chlorella ellipsoidea
 Chlorella fusca
 Chlorella kessleri
 Chlorella lobophora
 Chlorella minutissima
 Chlorella protothecoides
 Chlorella saccharophila
 Chlorella sorokiniana
 Chlorella vulgaris
 Chlorococcopsis minuta
 Coleochaete scutata
 Coleochaete orbicularis
 Dunaliella parva
 Dunaliella salina
 Friedmannia israeliensis
 Hydrodictyon reticulatum
 Klebsormidium flaccidum
 Nanochlorum eucaryotum
 Neochloris aquatica
 Neochloris vigenis
 Parietochloris pseudoalveolaris
 Pediatrum duplex
 Prototheca wickerhamii
 Prototheca zopfii
 Scenedesmus obliquus
 Spermatozopsis similis
 Tetraselmis striata
 Trebouxia impressa
 Trebouxia magna
 Trebouxia asymmetrica
 Volvox carteri

CHAROPHYTA

Chlorokybus atmophyticus
 Nitella sp.

ASSEMBLAGE CHROMOBIONTS

CHRYSOPHYTA

Hibberdia magna
 Mallomonas papillosa
 Mallomonas striata
 Ochromonas danica
 Synura spinosa

DINOPHYTA

Alexandrium tamarense
 Emilia huxleyi 1
 Emilia huxleyi 2
 Symbiodinium microadriaticum
 Symbiodinium pilosum
 Symbiodinium sp.
 Tribonema aequale

PHAEOPHYTA

Costaria costata
 Fucus gardneri
 Bacillaria paxillifer
 Cyllindrotheca closterium
 Nannochloropsis salina
 Nitzschia apiculata
 Rhizosolenia setigera
 Skeletonema costatum
 Stephanopyxis broschii

ASSEMBLAGE CILIATES

CILIOPHYTA

Blepharisma americanum
 Colpidium campylum
 Colpoda inflata
 Euplotes aediculatus
 Glaucocystis chattoni
 Metopus palaeformis
 Onychodromus quadricornutus
 Opisthonecta henneguyi
 Oxytricha granulifera

Table 1. *continued*

Oxytricha nova	Giardia duodenalis
Paramecium tetraurelia	Giardia muris
Stylonychia pustulata	
Tetrahymena australis	ASSEMBLAGE RHIZOPODS
Tetrahymena borealis	AMOEBOZOA
Tetrahymena canadensis	Acanthamoeba castellanii 1
Tetrahymena capricornis	Acanthamoeba castellanii 2
Tetrahymena hegewischi	Acanthamoeba palestinensis
Tetrahymena hyperangularis	Entamoeba histolytica
Tetrahymena malaccensis	Hartmannella vermiformis 1
Tetrahymena nanneyi	Hartmannella vermiformis 2
Tetrahymena patula	Naegleria gruberi
Tetrahymena pigmentosa	Paratetramitus jugosus
Tetrahymena pyriformis	Tetramitus rostratus
Tetrahymena thermophila 1	Vahlkampfia lobospinosa
Tetrahymena thermophila 2	
Tetrahymena tropicalis	EUMYCETOZOA
ASSEMBLAGE CRYPTOMONADS	Dictyostelium discoideum
CRYPTOPHYTA	Physarum polycephalum
Cryptomonas phi 1	
Cryptomonas phi 2	ASSEMBLAGE RHODOPHYTES
Pyrenomonas salina 1	RHODOPHYTA
Pyrenomonas salina 2	Gracilaria lemaneiformis
	Gracilaria tikvahiae
ASSEMBLAGE DINOFLAGELLATES	Gracilaria verrucosa
PERIDINEA	Gracilariopsis sp.
Cryptocodinium cohnii	Palmaria palmata
Cryptosporidium muris 1	
Cryptosporidium muris 2	ASSEMBLAGE SPOROZOA
Cryptosporidium parvum 1	APICOMPLEXA
Cryptosporidium parvum 2	Babesia bigemina 1
Prorocentrum micans	Babesia bigemina 2
	Babesia bigemina 3
ASSEMBLAGE EUGLENOZOA	Babesia bovis
EUGLENOPHYTA	Babesia caballi
Euglena gracilis	Babesia equi
	Babesia rodhaini
KINETOPLASTIDEA	Plasmodium berghei 1
Bodo caudatus	Plasmodium berghei 2
Crithidia fasciculata	Plasmodium cynomolgi 1
Endotrypanum monterogeii	Plasmodium cynomolgi 2
Leishmania amazonensis	Plasmodium falciparum 1
Leishmania brasiliensis	Plasmodium falciparum 2
Leishmania donovani	Plasmodium fragile
Leishmania major	Plasmodium gallinaceum
Leishmania tarentolae 1	Plasmodium lophurae
Leishmania tarentolae 2	Plasmodium malariae
Leptomonas sp.	Plasmodium vivax
Tritrichomonas foetus	Sarcocystis muris
Trypanosoma brucei	Theileria annulata
Trypanosoma cruzi 1	Theileria buffeli
Trypanosoma cruzi 2	Theileria parva
	Toxoplasma gondii
ASSEMBLAGE MASTIGOMYCETES	
CHYTRIDIOMYCOTA	ARCHAEA
Blastocladiella emersonii	EURYARCHAEOTA
Chytridium confervae	HALOBACTERIA
Neocallimastix frontalis	Halobacterium cutirubrum
Neocallimastix jayonii	Halobacterium halobium
Neocallimastix sp.	Halobacterium marismortui 1
Piromonas communis	Halobacterium marismortui 2
Spizellomyces acuminatus	Halobacterium volcanii
Achlya bisexualis	Halobacterium sp.
Lagenidium giganteum	Halococcus morrhuae 1 ATCC 17082
Phytophthora megasperma 1	Halococcus morrhuae 2 NRC 16008, NCMB 746
Phytophthora megasperma 2	Haloferax mediterranei ATCC 33500
	Natronobacterium magadii NCMB 2190
ASSEMBLAGE MICROSPORIDIA	
MICROSPORIDIA	METHANOBACTERIALES
Encephalitozoon cuniculi	Methanobacterium bryantii
Vairimorpha necatrix	Methanobacterium formicicum DSM 1312
ASSEMBLAGE POLYMASTIGOTES	Methanobacterium thermoautotrophicum 1
Giardia ardeae	Methanobacterium thermoautotrophicum 2
Giardia intestinalis	Methanobacterium thermoformicum 1
	Methanobacterium thermoformicum 2

Methanobacterium thermoformicium 3
 Methanobacterium thermoformicium 4
 Methanobacterium thermoformicium 5
 Methanobacterium thermoformicium 6
 Methanobacterium thermoformicium 7
 Methanobacterium thermoformicium 8
 Methanobacterium thermoformicium 9
 Methanobrevibacter arboriphilus
 Methanosphaera stadtmanii
 Methanothermus fervidus 1
 Methanothermus fervidus 2

METHANOCOCCALES

Methanococcus igneus DSM 5666
 Methanococcus jannaschii
 Methanococcus thermolithotrophicus
 Methanococcus voltae
 Methanococcus vannielii

METHANOMICROBIUM GROUP

Methanocorpusculum parvum DSM 3823
 Methanogenium cariaci DSM 1497
 Methanogenium marisnigri DSM 1498
 Methanogenium organophilum DSM 3596
 Methanogenium thermophilum DSM 3915
 Methanohalophilus mahii DSM 5219
 Methanohalophilus zhilinae
 Methanohalophilus sp. 1
 Methanohalophilus sp. 2 DSM 3243
 Methanolobus tindarius DSM 2278
 Methanomicrobium mobile DSM 1539
 Methanoplanus limicola DSM 2279
 Methanoseta concilii DSM 3013
 Methanoseta thermoacetophila DSM 3870
 Methanosarcina acidivorans DSM 2834
 Methanosarcina barkeri DSM 1538
 Methanosarcina frisia DSM 3318
 Methanosarcina frisius
 Methanosarcina thermophila DSM 1825
 Methanosarcina sp. DSM 4659
 Methanospirillum hungatei
 Methanotherix soehngenii
 Methylococcoides methylutens DSM 2657

THERMOCOCCALES

Thermococcus celer DSM 2476

THERMOPLASMA

Thermoplasma acidophilum

ARCHAEOGLOBALES

Archaeoglobus fulgidus

METHANOPYRALES

Methanopyrus kandleri DSM 6324

CRENARCHAEOTA

Desulfurococcus mobilis
 Pyrodictium occultum DSM 2709
 Sulfolobus shibatae DSM 5389
 Sulfolobus solfataricus
 Thermofilum pendens DSM 2475
 Thermoproteus tenax

BACTERIA

PROTEOBACTERIA ALPHA

Afipia clevelandensis
 Afipia felis ATCC 53690
 Agrobacterium tumefaciens DSM 30105
 Anaplasma marginale
 Ancylobacter aquaticus ATCC 25396
 Azospirillum lipoferum
 Bangasternus orientalis endosymbiont
 Bartonella bacilliformis 1 ATCC 35685
 Bartonella bacilliformis 2 NCTC 12138
 Bartonella bacilliformis 3 ATCC 35685

Beijerinckia indica
 Blastobacter denitrificans LMG 8443 (T)
 Bradyrhizobium japonicum LMG 6138 (T)
 Brucella abortus
 Caulobacter bacteroides
 Caulobacter crescentus 1
 Caulobacter crescentus 2
 Caulobacter crescentus 3
 Caulobacter subvibrioides
 Caulobacter sp. 1
 Caulobacter sp. 2
 Caulobacter sp. 3
 Caulobacter sp. 4
 Caulobacter sp. 5
 Caulobacter sp. 6
 Caulobacter sp. 7
 Caulobacter sp. 8
 Caulobacter sp. 9
 Caulobacter sp. 10
 Cowdria ruminantium 1
 Cowdria ruminantium 2
 Ehrlichia canis 1
 Ehrlichia canis 2
 Ehrlichia chaffeensis
 Ehrlichia equi
 Ehrlichia ewingii 1
 Ehrlichia ewingii 2
 Ehrlichia phagocytophila 1
 Ehrlichia phagocytophila 2
 Ehrlichia risticii
 Ehrlichia sennetsu 1
 Ehrlichia sennetsu 2
 Erythrobacter longus 1
 Erythrobacter longus 2
 Erythrobacter longus 3
 Erythrobacter sp.
 Flavobacterium capsulatum
 Flavobacterium devorans
 Hirschia baltica
 Hyphomicrobium vulgare
 Hyphomonas jannaschiana
 Hyphomonas sp.
 Magnetite-containing magnetic vibrio
 Magnetospirillum gryphiswaldense DSM 6361
 Magnetospirillum magnetotacticum ATCC 31632
 Methylobacterium extorquens 1
 Methylobacterium extorquens 2
 Methylobacterium organophilum
 Methylobacterium sp. 1
 Methylobacterium sp. 2
 Methylobacterium sp. 3
 Methylocystis parvus
 Methylosinus sporium
 Methylosinus trichosporium
 Methylosinus sp. 1
 Methylosinus sp. 2
 Methylosporovibrio methanicus
 Porphyrobacter neustonensis 1
 Porphyrobacter neustonensis 2
 Pseudomonas diminuta
 Rhinocyllus conicus endosymbiont
 Rhodobacter capsulatus 1
 Rhodobacter capsulatus 2
 Rhodobacter sphaeroides 1
 Rhodobacter sphaeroides 2
 Rhodobacter sphaeroides 3
 Rhodomicrobium vannielii
 Rhodopseudomonas acidophila
 Rhodopseudomonas globiformis
 Rhodopseudomonas marina
 Rhodopseudomonas palustris
 Rhodospirillum centenum
 Rhodospirillum fulvum
 Rhodospirillum molischanum
 Rhodospirillum rubrum
 Rhodospirillum salaxigenes
 Rhodospirillum salinarum

Table 1. continued

Rhodospirillum sodomense
 Rickettsia prowazekii Brienl
 Rickettsia rickettsii
 Rickettsia typhi Wilmington
 Rochalimaea americana
 Rochalimaea quintana 1
 Rochalimaea quintana 2
 Rochalimaea saintelizabethsina
 Rochalimaea vinsonii 1
 Rochalimaea vinsonii 2
 Roseobacter denitrificans 1
 Roseobacter denitrificans 2
 Simonsiella muelleri
 Sitophilus oryzae endosymbiont
 Wolbachia pipientis
 Zoogloea ramigera

PROTEOBACTERIA BETA

Alcaligenes eutrophus
 Alcaligenes faecalis ATCC 8750 (T)
 Alcaligenes xylosoxidans ATCC 15173 (T)
 Bordetella bronchiseptica
 Chromobacterium fluviale ATCC 33051 (T)
 Chromobacterium violaceum ATCC 12472 (T)
 Eikenella corrodens 1 ATCC 23834 (T)
 Eikenella corrodens 2 FDC 373
 Eikenella corrodens 3 FDC 558
 Eikenella corrodens 4 FDC 1073
 Eikenella sp.
 Gallionella ferruginea
 Kingella denitrificans 1 ATCC 33394 (T)
 Kingella denitrificans 2
 Kingella kingae ATCC 23330 (T)
 Kingella orale
 Leptothrix discophora
 Methylobacillus flagellatum
 Methylobacillus glycogenes
 Methylomonas methanica
 Methylomonas methylovora
 Methylophilus methylotrophus
 Neisseria animalis
 Neisseria canis
 Neisseria denitrificans 1 ATCC 14686 (T)
 Neisseria denitrificans 2
 Neisseria elongata 1
 Neisseria elongata 2
 Neisseria flavescens
 Neisseria gonorrhoeae 1 NCTC 83785
 Neisseria gonorrhoeae 2
 Neisseria macaca
 Neisseria polysaccharea
 Nitrosococcus mobilis
 Nitrosolobus multififormis 1
 Nitrosolobus multififormis 2
 Nitrosomonas europae
 Nitrosomonas europaea
 Nitrosomonas eutropha
 Nitrosovibrio tenuis 1
 Nitrosovibrio tenuis 2
 Nitrosovibrio tenuis 3
 Nitrospira briensis
 Pseudomonas cepacia ATCC 25416 (T)
 Pseudomonas testosteroni ATCC 11996
 Rhodocyclus gelatinosus
 Rhodocyclus purpureus
 Sphaerotilus natans
 Spirillum volutans ATCC 19554 (T)
 Thiobacillus thioparus ATCC 8158
 Vitreoscilla stercoraria 1
 Vitreoscilla stercoraria 2
 Zoogloea ramigera 1
 Zoogloea ramigera 2
 Zoogloea ramigera 3

PROTEOBACTERIA GAMMA*^b

Acinetobacter calcoaceticus
 Alteromonas vaga ATCC 27119
 Arhodomonas oleiferhydrans
 Bacteroides nodosus
 Bathymodiolus thermophilus gill symbiont
 Calyptogenia magnifica symbiont
 Cardiobacterium hominis ATCC 16826 (T)
 Chromatium tepidum
 Chromatium vinosum ATCC 17899
 Codakia orbicularis gill symbiont
 Coxiella burnetii
 Ectothiorhodospira halochloris
 Ectothiorhodospira halophila
 Ectothiorhodospira shaposhnikovi
 Flavobacterium halmophilum
 Flavobacterium lutescens
 Halomonas elongata ATCC 33173
 Kingella indologenes ATCC 25869 (T)
 Legionella bozemanii NCTC 11368 (T)
 Legionella erythra NCTC 11977 (T)
 Legionella hackeliae NCTC 11979 (T)
 Legionella longbeachae NCTC 11477 (T)
 Legionella maceachernii NCTC 11982
 Legionella micdadei NCTC 11371 (T)
 Legionella pneumophila 1 NCTC 11192 (T)
 Legionella pneumophila 2 NCTC 11286
 Legionella pneumophila 3 NCTC 11233 (T)
 Legionella pneumophila 4 NCTC 11405
 Legionella pneumophila 5
 Legionella spiritensis NCTC 11990 (T)
 Legionella sp.
 Lucinoma aequizonata gill symbiont
 Marinobacter hydrocarbonoclasticus
 Methylococcus capsulatus
 Methylococcus luteus
 Methylomonas albus
 Methylomonas methanica
 Methylomonas rubra
 Methylomonas sp.
 Nitrosococcus oceanus 1
 Nitrosococcus oceanus 2
 Oceanospirillum linum ATCC 11336 (T)
 Pseudomonas aeruginosa 1 ATCC 11996
 Pseudomonas aeruginosa 2 ATCC 25330
 Pseudomonas mendocina
 Riftia pachyptila trophosome symbiont
 Solemya reidi symbiont
 Solemya velum symbiont
 Thiobacillus hydrothermalis
 Xanthomonas maltophilia
 Xylella fastidiosa

PROTEOBACTERIA GAMMA

Actinobacillus actinomycetemcomitans 1 ATCC 29524
 Actinobacillus actinomycetemcomitans 2 ATCC 29523
 Actinobacillus actinomycetemcomitans 3 ATCC 33384 (T)
 Actinobacillus actinomycetemcomitans 4 FDC Y4
 Actinobacillus actinomycetemcomitans 5 ATCC 29522
 Actinobacillus capsulatus 1 NCTC 11408 (T)
 Actinobacillus capsulatus 2 CCUG 19799
 Actinobacillus capsulatus 3 CCUG 12396 (T)
 Actinobacillus equuli NCTC 8529 (T)
 Actinobacillus hominis
 Actinobacillus lignieresii 1 ATCC 19393 (T)
 Actinobacillus lignieresii 2 NCTC 4189 (T)
 Actinobacillus pleuropneumoniae ATCC 27088 (T)
 Actinobacillus salpingitidis
 Actinobacillus seminis ATCC 15768 (T)
 Actinobacillus suis ATCC 15557
 Actinobacillus ureae
 Acyrthosyphon pisum symbiont P
 Acyrthosyphon pisum symbiont S

- Aeromonas caviae* 1 NCIMB 13016 (T)
Aeromonas caviae 2 ATCC 15467
Aeromonas eucrenophila NCIMB 74 (T)
Aeromonas hydrophila 1
Aeromonas hydrophila 2 ATCC 7966 (T)
Aeromonas jandaei ATCC 49568 (T)
Aeromonas media ATCC 33907 (T)
Aeromonas salmonicida 1 NCIMB 1102 (T)
Aeromonas salmonicida 2 NCIMB 1102
Aeromonas salmonicida 3 NCIMB 1110
Aeromonas schubertii DSM 4882 (T)
Aeromonas sobria NCIMB 12065 (T)
Aeromonas trota ATCC 49657 (T)
Aeromonas veronii NCIMB 13015 (T)
Aeromonas sp. ATCC 35941
Alteromonas haloplanktis ATCC 14393
Arsenophonus nasoniae ATCC 49151 (T)
Barophile 1
Barophile 2
Bisgaard Taxon 2
Bisgaard Taxon 3
Bisgaard Taxon 5
Bisgaard Taxon 6
Bisgaard Taxon 7
Bisgaard Taxon 8
Bisgaard Taxon 9
Bisgaard Taxon 13
Bisgaard Taxon 14 1
Bisgaard Taxon 14 2
Buchnera aphidicola 1
Buchnera aphidicola 2
Buchnera aphidicola 3
Buchnera aphidicola 4
Buchnera aphidicola 5
Buchnera aphidicola 6
Buchnera aphidicola 7
Buchnera aphidicola 8
Buchnera aphidicola 9
Buchnera aphidicola 10
Citrobacter freundii
Cryptosaras couesi symbiont
Erwinia carotovora
Erwinia herbicola
Escherichia coli
Euscelidius variegatus parasite
Haemophilus aegyptius NCTC 8502 (T)
Haemophilus aphrophilus ATCC 33389 (T)
Haemophilus ducreyi 1 CIP 542 (T)
Haemophilus ducreyi 2 CIP 542 (T)
Haemophilus ducreyi 3
Haemophilus ducreyi 4 ATCC 27722
Haemophilus haemoglobinophilus NCTC 1659 (T)
Haemophilus haemolyticus NCTC 10659 (T)
Haemophilus influenzae ATCC 33391 (T)
Haemophilus paracuniculus ATCC 29986 (T)
Haemophilus paragallinarum NCTC 11296 (T)
Haemophilus parahaemolyticus NCTC 8479 (T)
Haemophilus parainfluenzae 1 ATCC 7901
Haemophilus parainfluenzae 2 ATCC 33392 (T)
Haemophilus paraphrophaemolyticus NCTC 10670 (T)
Haemophilus paraphrophilus 1 ATCC 29241 (T)
Haemophilus paraphrophilus 2 ATCC 29242
Haemophilus parasuis 1 NCTC 4557 (T)
Haemophilus parasuis 2
Haemophilus segnis ATCC 33393 (T)
Haemophilus somnus
Haemophilus sp.
Haemophilus taxon
Hafnia alvei
Melanocetus johnsoni symbiont
Pasteurella aerogenes ATCC 27883 (T)
Pasteurella anatis ATCC 43329 (T)
Pasteurella avium NCTC 11297 (T)
Pasteurella betti
Pasteurella canis ATCC 43326 (T)
Pasteurella dagmatis ATCC 43325 (T)
Pasteurella gallinarum NCTC 11188 (T)
Pasteurella haemolytica 1 NCTC 10624
Pasteurella haemolytica 2 NCTC 9380 (T)
Pasteurella langaa ATCC 43328 (T)
Pasteurella multocida NCTC 10322 (T)
Pasteurella pneumotropica NCTC 8141 (T)
Pasteurella stomatis ATCC 43327 (T)
Pasteurella testudinis
Pasteurella volantium 1 NCTC 4101
Pasteurella volantium 2 NCTC 3438 (T)
Pasteurella sp. 1 CCUG 19794
Pasteurella sp. 2 CCUG 18782
Photobacterium phosphoreum
Piscirickettsia salmonis
Plesiomonas shigelloides 1
Plesiomonas shigelloides 2 NCIMB 9242 (T)
Proteus vulgaris 1
Proteus vulgaris 2
Ruminobacter amylophilus DSM 1361 (T)
Serratia entomophila ATCC 43705
Serratia ficaria ATCC 33105
Serratia fonticola ATCC 29844
Serratia grimesii ATCC 14460
Serratia liquefaciens ATCC 27592
Serratia marcescens 1 ATCC 13880
Serratia marcescens 2
Serratia odorifera ATCC 33077
Serratia plymuthica ATCC 183
Serratia proteamaculans ATCC 19323
Serratia rubidaea ATCC 27593
Sitophilus zeamais endosymbiont 1
Sitophilus zeamais endosymbiont 2
Thiomicrospira sp.
Vibrio alginolyticus ATCC 17749 (T)
Vibrio anguillarum NCMB 6, ATCC 12964 (T)
Vibrio campbellii ATCC 25920 (T)
Vibrio diazotrophicus ATCC 33466 (T)
Vibrio harveyi 1
Vibrio harveyi 2 ATCC 14126 (T)
Vibrio hollisae ATCC 33564 (T)
Vibrio natriegens ATCC 14048 (T)
Vibrio parahaemolyticus 1
Vibrio parahaemolyticus 2 ATCC 17802 (T)
Vibrio proteolyticus ATCC 15338 (T)
Vibrio vulnificus ATCC 27562 (T)
Wolbachia persica ATCC VR 331
Xenorhabdus nematophilus
Yersinia enterocolitica
- PROTEOBACTERIA DELTA**
- Angiococcus disciformis*
Archangium gephyra
Bdellovibrio bacteriovorus
Bdellovibrio stolpii
Chondromyces apiculatus
Chondromyces crocatus
Cystobacter fuscus
Desulfobacter curvatus DSM 3379
Desulfobacter hydrogenophilus DSM 3380
Desulfobacter lactus DSM 3381
Desulfobacter postgatei DSM 2034
Desulfobacter sp. 1 DSM 2035
Desulfobacter sp. 2 DSM 2057
Desulfobacterium autotrophicum DSM 3382
Desulfobacterium niacini DSM 2650
Desulfobacterium vacuolatum DSM 3385
Desulfobulbus propionicus ATCC 33891
Desulfobulbus sp. DSM 2058
Desulfococcus multivorans ATCC 33890
Desulfomonas pigra ATCC 29098
Desulfomonile tiedjei ATCC 49306
Desulfosarcina variabilis 1
Desulfosarcina variabilis 2 DSM 2060
Desulfovibrio africanus

Table 1. *continued*

Desulfovibrio baarsii DSM 2075	GREEN SULFUR
Desulfovibrio baculatus DSM 1743	Chlorobium limicola
Desulfovibrio desulfuricans 1 ATCC 27774	Chlorobium tepidum ATCC 49652
Desulfovibrio desulfuricans 2	Chlorobium vibrioforme
Desulfovibrio desulfuricans 3	Clathrochloris sulfurica
Desulfovibrio gigas ATCC 19364	
Desulfovibrio longus	FLAVOBACTERIA AND RELATIVES
Desulfovibrio salexigens ATCC 14822	Antarcticum vesiculatum
Desulfovibrio sapovorans ATCC 33892	Bacteroides distasonis
Desulfovibrio vulgaris DSM 644	Bacteroides fragilis 1 ATCC 25285
Desulfovibrio sp.	Bacteroides fragilis 2
Desulfuromonas acetoxidans DSM 684	Bacteroides thetaiotaomicron
Magnetotactic bacterium	Bacteroides vulgatus
Melittangium lichenicola	Capnocytophaga gingivalis
Myxococcus coralloides	Capnocytophaga ochracea
Myxococcus xanthus	Capnocytophaga sputigena ATCC 33612
Nannocystis exedens	Cytophaga aquatilis
Polyangium cellulosum	Cytophaga diffluens
Stigmatella aurantiaca	Cytophaga fermentans
	Cytophaga flevensis
PROTEOBACTERIA EPSILON	Cytophaga heparina IFO 12017, ATCC 13125
Bacteroides gracilis	Cytophaga hutchinsonii
Bacteroides ureolyticus	Cytophaga johnsonae 1
Campylobacter coli 1	Cytophaga johnsonae 2
Campylobacter coli 2	Cytophaga latercula
Campylobacter concisus 1	Cytophaga lytica ATCC 23178
Campylobacter concisus 2	Cytophaga marinoflava
Campylobacter curvus 1	Cytophaga salmonicolor
Campylobacter curvus 2	Flavobacterium aquatile ATCC 11947
Campylobacter fetus	Flavobacterium balustinum
Campylobacter fetus subsp. fetus ATCC 27374	Flavobacterium breve
Campylobacter fetus subsp. venerealis ATCC 19438	Flavobacterium ferrugineum ATCC 13524
Campylobacter hyointestinalis 1	Flavobacterium gleum
Campylobacter hyointestinalis 2 ATCC 25317	Flavobacterium gondwanense
Campylobacter jejuni 1	Flavobacterium indologenes
Campylobacter jejuni 2	Flavobacterium indoltheticum
Campylobacter lari	Flavobacterium meningosepticum
Campylobacter mucosalis	Flavobacterium odoratum
Campylobacter rectus 1	Flavobacterium salegens
Campylobacter rectus 2	Flavobacterium spiritivorum
Campylobacter showae 1	Flavobacterium thalpophilum
Campylobacter showae 2	Flavobacterium uliginosum ATCC 14397
Campylobacter sputorum 1 LMG 7795	Flectobacillus glomeratus
Campylobacter sputorum 2	Flectobacillus major ATCC 29496
Flexispira rappini	Flectobacillus marinus ATCC 43824
Helicobacter acinonyx 1	Flexibacter aggregans 1
Helicobacter acinonyx 2	Flexibacter aggregans 2
Helicobacter cinaedi	Flexibacter aurantiacus ATCC 23107
Helicobacter felis 1 ATCC 49179	Flexibacter canadensis ATCC 29591
Helicobacter felis 2	Flexibacter columnaris
Helicobacter felis 3	Flexibacter elegans 1
Helicobacter fennelliae	Flexibacter elegans 2
Helicobacter muridarum	Flexibacter elegans 3
Helicobacter mustelae 1 ATCC 43772	Flexibacter elegans 4
Helicobacter mustelae 2	Flexibacter flexilis ATCC 23079
Helicobacter pylori	Flexibacter litoralis
Helicobacter sp. 1	Flexibacter maritimus 1
Helicobacter sp. 2	Flexibacter maritimus 2
Helicobacter sp. 3	Flexibacter polymorphus
Helicobacter sp. 4	Flexibacter roseolus
Helicobacter sp. 5	Flexibacter ruber
Helicobacter sp. 6	Flexibacter sancti ATCC 23092
Helicobacter sp. 7	Flexibacter tractuosus
Helicobacter sp. 8	Halicomenobacter hydrossis
Helicobacter sp. 9	Microscilla aggregans subsp. catalytica
Helicobacter sp. 10	Microscilla arenaria
Helicobacter sp. 11	Microscilla furvescens
Helicobacter sp. 12	Microscilla marina
Wolinella succinogenes 1 ATCC 29453	Microscilla sericea
Wolinella succinogenes 2	Runella slithyformis ATCC 29530
Wolinella succinogenes 3	Saprospira grandis
	Sphingobacter mizutae
PROTEOBACTERIA, UNCERTAIN AFFILIATION	Spirosoma linguale ATCC 23276
Thiobacillus thiooxidans DSM 612	Sporocytophaga cauliformis

Weeksella virosa
Weeksella zoohelcum

CHLAMYDIAE

Chlamydia pneumoniae
Chlamydia psittaci
Chlamydia trachomatis

FIBROBACTER

Fibrobacter intestinales 1
Fibrobacter intestinales 2
Fibrobacter intestinales 3
Fibrobacter intestinales 4
Fibrobacter intestinales 5
Fibrobacter succinogenes 1
Fibrobacter succinogenes 2
Fibrobacter succinogenes 3
Fibrobacter succinogenes 4
Fibrobacter succinogenes 5
Fibrobacter succinogenes 6
Fibrobacter succinogenes 7
Fibrobacter succinogenes 8
Fibrobacter succinogenes 9
Fibrobacter succinogenes 10

SPIROCHETES

Borrelia anserina 1
Borrelia anserina 2
Borrelia burgdorferi
Borrelia burgdorferi 1
Borrelia burgdorferi 2
Borrelia burgdorferi 3
Borrelia burgdorferi 4
Borrelia burgdorferi 5
Borrelia burgdorferi 6
Borrelia burgdorferi 7 ATCC 35210 (T)
Borrelia burgdorferi 8
Borrelia burgdorferi 9
Borrelia burgdorferi 10
Borrelia burgdorferi 11
Borrelia burgdorferi 12
Borrelia coriacea ATCC 43381
Borrelia hermsii 1 ATCC 35209
Borrelia hermsii 2
Borrelia hermsii 3
Borrelia hermsii 4
Borrelia hermsii 5
Borrelia sp.
Leptonema illini
Leptospira illini
Leptospira interrogans 1 ATCC 23606
Leptospira interrogans 2
Leptospira sp.
Serpula hyodysenteriae 1 ATCC 27164 (T)
Serpula hyodysenteriae 2
Serpula hyodysenteriae 3
Serpula innocens 1 ATCC 29796 (T)
Serpula innocens 2
Spirochaeta aurantia ATCC 25082 (T)
Spirochaeta bajacaliforniensis ATCC 35968 (T)
Spirochaeta halophila ATCC 29478 (T)
Spirochaeta isovalerica
Spirochaeta litoralis ATCC 27000 (T)
Spirochaeta stenostrepta ATCC 25083 (T)
Spirochaeta thermophila DSM 6192
Spirochaeta zuelzeri ATCC 19044 (T)
Spirochaeta sp. 1
Spirochaeta sp. 2
Treponema bryantii ATCC 33254 (T)
Treponema denticola ATCC 33520
Treponema pallidum 1
Treponema pallidum 2
Treponema pectinovorum ATCC 33768 (T)
Treponema phagedenis
Treponema saccharophilum ATCC 43261 (T)
Treponema succinifaciens ATCC 33096 (T)

Treponema sp. 1 ATCC 43811
Treponema sp. 2
Treponema sp. 3
Treponema sp. 4

FUSOBACTERIUM AND RELATIVES

Bacteroides termitidis
Fusobacterium alocis ATCC 35896 (T)
Fusobacterium gonidiaformans ATCC 25563 (T)
Fusobacterium gonidiformans
Fusobacterium mortiferum 1
Fusobacterium mortiferum 2 ATCC 25557 (T)
Fusobacterium necrogenes ATCC 25556 (T)
Fusobacterium necrophorum ATCC 25286 (T)
Fusobacterium nucleatum
Fusobacterium nucleatum ssp. animalis NCTC 12276 (T)
Fusobacterium nucleatum ssp. fusiformis NCTC 11326 (T)
Fusobacterium nucleatum ssp. nucleatum ATCC 25586 (T)
Fusobacterium nucleatum ssp. polymorphum ATCC 10953
Fusobacterium perfoetens
Fusobacterium periodonticum ATCC 33693 (T)
Fusobacterium russii 1
Fusobacterium russii 2 ATCC 25533 (T)
Fusobacterium simiae 1
Fusobacterium simiae 2 ATCC 33568 (T)
Fusobacterium ulcerans NCTC 12111 (T)
Fusobacterium varium 1
Fusobacterium varium 2 NCTC 10560 (T)
Leptotrichia buccalis
Propionigenium modestum

CYANOBACTERIA

Anabaena sp.
Anacystis nidulans
Cyanobacterium sp.
Cyanophora paradoxa cyanelle
Mastigocladus laminosus
Prochlorococcus marinus
Prochloron sp.
Prochlorothrix hollandica

GRAM POSITIVES AND RELATIVES, LOW G+C

Acetomaculum ruminis
Acetonema longum DSM 6540 (T)
Acholeplasma entomophilum ATCC 43706
Acholeplasma laidlawii
Acholeplasma modicum ATCC 29102
Acidaminococcus fermentans ATCC 25085
Aerococcus urinae NCTC 12142 (T)
Aerococcus viridans
Alloiococcus otitis
Anaeroplasma abactoclasticum ATCC 27879
Anaeroplasma bactoclasticum ATCC 27112
Anaeroplasma varium ATCC 43167
Asteroleplasma anaerobium ATCC 27880
Bacillus acidocaldarius 1 ATCC 43034
Bacillus acidocaldarius 2 DSM 446 (T)
Bacillus acidoterrestris 1 DSM 3922
Bacillus acidoterrestris 2 DSM 3923
Bacillus alcalophilus DSM 485
Bacillus alvei 1 ATCC 6344
Bacillus alvei 2 NCDO 1153
Bacillus amyloliquefaciens ATCC 23350
Bacillus amylolyticus NCIMB 8144
Bacillus aneurinolyticus NCIMB 10056
Bacillus anthracis
Bacillus atropheus NCIMB 12899
Bacillus azotofixans ATCC 35681
Bacillus azotoformans ATCC 29788
Bacillus badius NCDO 1760
Bacillus benzeovorans NCIMB 12555
Bacillus brevis 1 NCIMB 9372
Bacillus brevis 2
Bacillus cereus 1 NCTC 11143
Bacillus cereus 2 NCDO 1771 (T)
Bacillus circulans NCDO 1775

Table 1. *continued*

<i>Bacillus coagulans</i> NCDO 1761	<i>Clostridium estertheticum</i> NCIMB 12511
<i>Bacillus cycloheptanicus</i> DSM 4006 (T)	<i>Clostridium fallax</i>
<i>Bacillus fastidiosus</i> DSM 91	<i>Clostridium histolyticum</i>
<i>Bacillus firmus</i> NCIMB 9366	<i>Clostridium innocuum</i> ATCC 14501
<i>Bacillus globisporus</i> 1 NCIMB 11434	<i>Clostridium kluyveri</i>
<i>Bacillus globisporus</i> 2 ATCC 23301, DSM 4 (T)	<i>Clostridium leptum</i>
<i>Bacillus gordonae</i> ATCC 29948	<i>Clostridium limosum</i>
<i>Bacillus insolitus</i> DSM 5	<i>Clostridium lituseburense</i>
<i>Bacillus kaustophilus</i> NCIMB 8547	<i>Clostridium ljungdahlii</i>
<i>Bacillus larvae</i> ATCC 9545	<i>Clostridium malenominatum</i>
<i>Bacillus laterosporus</i> 1 ATCC 6344, DSM 25	<i>Clostridium mangenotii</i>
<i>Bacillus laterosporus</i> 2 NCDO 1763	<i>Clostridium mayombeyi</i> DSM 6539 (T)
<i>Bacillus lautus</i> NCIMB 12780	<i>Clostridium novyi</i>
<i>Bacillus lentimorbus</i> ATCC 14707	<i>Clostridium oceanicum</i>
<i>Bacillus lentus</i> NCDO 1127	<i>Clostridium oroticum</i>
<i>Bacillus licheniformis</i> NCDO 1772	<i>Clostridium paraperfringens</i>
<i>Bacillus macerans</i> 1 ATCC 8244, DSM 24	<i>Clostridium pasteurianum</i>
<i>Bacillus macerans</i> 2 NCDO 1764	<i>Clostridium perfringens</i> 1
<i>Bacillus macquariensis</i> 1 DSM/ATCC 23464 (T)	<i>Clostridium perfringens</i> 2
<i>Bacillus macquariensis</i> 2 NCTC 10419	<i>Clostridium piliforme</i>
<i>Bacillus maroccanus</i> NCIMB 10500	<i>Clostridium purinolyticum</i>
<i>Bacillus medusa</i> NCIMB 10437	<i>Clostridium quercicolum</i>
<i>Bacillus megaterium</i> DSM 32	<i>Clostridium ramosum</i> ATCC 25582
<i>Bacillus mycoides</i> DSM 2048 (T)	<i>Clostridium scatologenes</i>
<i>Bacillus pabuli</i> NCIMB 12781	<i>Clostridium sordellii</i>
<i>Bacillus pantothenicus</i> NCDO 1765	<i>Clostridium sporogenes</i>
<i>Bacillus pasteurii</i> NCIMB 8841	<i>Clostridium sporosphaeroides</i>
<i>Bacillus polymyxa</i> 1 DSM 36	<i>Clostridium sticklandii</i> 1
<i>Bacillus polymyxa</i> 2 NCDO 1774	<i>Clostridium sticklandii</i> 2
<i>Bacillus popilliae</i> ATCC 14706	<i>Clostridium subterminale</i>
<i>Bacillus psychrophilus</i> 1 ATCC 23304	<i>Clostridium symbiosum</i>
<i>Bacillus psychrophilus</i> 2 ATCC 23304, DSM 3 (T)	<i>Clostridium tetanomorphum</i> NCIMB 11547
<i>Bacillus psychrophilus</i> 3 ATCC 23306, DSM 2273	<i>Clostridium thermaceticum</i>
<i>Bacillus psychrosaccharolyticus</i> ATCC 23296	<i>Clostridium thermoaceticum</i>
<i>Bacillus pulvifaciens</i> NCDO 1141	<i>Clostridium thermoautotrophicum</i> 1
<i>Bacillus pumilus</i> NCDO 1766	<i>Clostridium thermoautotrophicum</i> 2
<i>Bacillus simplex</i> DSM 1321	<i>Clostridium thermohydrosulfuricum</i>
<i>Bacillus smithii</i> DSM 4216	<i>Clostridium thermosaccharolyticum</i>
<i>Bacillus sphaericus</i> NCDO 1767	<i>Clostridium thermosulfurogenes</i>
<i>Bacillus stearothermophilus</i> 1	<i>Clostridium tyrobutyricum</i> 1
<i>Bacillus stearothermophilus</i> 2 NCDO 1768	<i>Clostridium tyrobutyricum</i> 2
<i>Bacillus subtilis</i> 1	<i>Desulfotomaculum nigrificans</i> NCIMB 8395 (T)
<i>Bacillus subtilis</i> 2 NCDO 1769	<i>Desulfotomaculum orientis</i> NCIMB 8382
<i>Bacillus thermoglucosadicus</i> ATCC 43742	<i>Desulfotomaculum ruminis</i> NCIMB 8452
<i>Bacillus thuringiensis</i> NCIMB 9134 (T)	<i>Enterococcus avium</i> NCDO 2369 (T)
<i>Brochothrix campestris</i> ATCC 43754 (T)	<i>Enterococcus casseliflavus</i> NCDO 2376
<i>Brochothrix thermosphacta</i> 1 NCDO 1676 (T)	<i>Enterococcus columbae</i> NCIMB 13013
<i>Brochothrix thermosphacta</i> 2	<i>Enterococcus dispar</i>
<i>Carnobacterium divergens</i> NCDO 2763 (T)	<i>Enterococcus durans</i> NCDO 596 (T)
<i>Carnobacterium gallinarum</i>	<i>Enterococcus faecalis</i>
<i>Carnobacterium mobile</i>	<i>Enterococcus faecium</i> NCDO 942 (T)
<i>Carnobacterium piscicola</i> NCDO 2762 (T)	<i>Enterococcus gallinarum</i> NCDO 2313 (T)
<i>Clostridium acetobutylicum</i> NCIMB 8052	<i>Enterococcus hirea</i> NCDO 1258 (T)
<i>Clostridium acidurici</i>	<i>Enterococcus malodoratus</i> NCDO 846 (T)
<i>Clostridium aminophilum</i>	<i>Enterococcus mundtii</i> NCDO 2375 (T)
<i>Clostridium aminovalericum</i>	<i>Enterococcus pseudoavium</i> NCDO 2138 (T)
<i>Clostridium aurantibutyricum</i> NCIMB 10659	<i>Enterococcus raffinosus</i> NCTC 12192 (T)
<i>Clostridium barati</i> 1 ATCC 27638	<i>Enterococcus sulfureus</i> NCDO 2379
<i>Clostridium barati</i> 2 ATCC 43756	<i>Epulopiscium</i> sp. 1
<i>Clostridium barkeri</i>	<i>Epulopiscium</i> sp. 2
<i>Clostridium beijerinckii</i> 1 DSM 791	<i>Erysipelothrix rhusiopathiae</i> ATCC 19414
<i>Clostridium beijerinckii</i> 2 NCIMB 9362	<i>Eubacterium alactolyticum</i> DSM 3980
<i>Clostridium botulinum</i> 1	<i>Eubacterium bifforme</i>
<i>Clostridium botulinum</i> 2	<i>Eubacterium limosum</i>
<i>Clostridium botulinum</i> 3	<i>Eubacterium tenue</i>
<i>Clostridium botulinum</i> 4 NCTC 10281	<i>Gemella haemolysans</i>
<i>Clostridium botulinum</i> 5 ATCC 25765	<i>Heliobacterium chlorum</i>
<i>Clostridium butyricum</i> 1 ATCC 43755	<i>Kurthia zopfii</i>
<i>Clostridium butyricum</i> 2 DSM 2478	<i>Lactobacillus acetolerans</i>
<i>Clostridium butyricum</i> 3 NCIMB 8082	<i>Lactobacillus acidophilus</i> 1 NCDO 1748 (T)
<i>Clostridium cadaveris</i>	<i>Lactobacillus acidophilus</i> 2
<i>Clostridium carnis</i>	<i>Lactobacillus agilis</i>
<i>Clostridium clostridiiformes</i>	<i>Lactobacillus alimentarius</i>
<i>Clostridium coccoides</i>	<i>Lactobacillus amylophilus</i>
<i>Clostridium cochlearium</i>	<i>Lactobacillus amylovorus</i>

- Lactobacillus animalis* 1 NCDO 2425 (T)
Lactobacillus animalis 2
Lactobacillus aviarius
Lactobacillus bif fermentans
Lactobacillus brevis 1 NCDO 1749 (T)
Lactobacillus brevis 2
Lactobacillus buchneri 1 NCDO 110 (T)
Lactobacillus buchneri 2
Lactobacillus carnis
Lactobacillus casei 1
Lactobacillus casei 2 NCDO 161 (T)
Lactobacillus casei 3
Lactobacillus cateniformis ATCC 25536 (T)
Lactobacillus confusus 1 NCDO 5186
Lactobacillus confusus 2 DSM 20196
Lactobacillus coryniformis
Lactobacillus delbrueckii 1
Lactobacillus delbrueckii 2 NCDO 213
Lactobacillus divergens
Lactobacillus farciminis
Lactobacillus fermentum 1 NCDO 1750 (T)
Lactobacillus fermentum 2
Lactobacillus fructivorans
Lactobacillus fructosus NCDO 2345 (T)
Lactobacillus gasseri 1 NCDO 2233 (T)
Lactobacillus gasseri 2
Lactobacillus halotolerans DSM 20190
Lactobacillus helveticus NCDO 2712 (T)
Lactobacillus hilgardii
Lactobacillus kandleri 1 NCDO 2753
Lactobacillus kandleri 2 DSM 20593
Lactobacillus lactis
Lactobacillus mali
Lactobacillus maltaromicus 1
Lactobacillus maltaromicus 2 JCM 1154
Lactobacillus minor 1 NCDO 1973
Lactobacillus minor 2 DSM 20014
Lactobacillus murinus
Lactobacillus oris NCDO 2160 (T)
Lactobacillus plantarum 1
Lactobacillus plantarum 2 NCDO 1752
Lactobacillus ruminis
Lactobacillus sake
Lactobacillus salivarius
Lactobacillus sanfrancisco 1 JCM 5668
Lactobacillus sanfrancisco 2
Lactobacillus sharpeae
Lactobacillus thermophilus
Lactobacillus vaginalis NCTC 12197
Lactobacillus vermiformis
Lactobacillus viridescens 1 NCDO 1655
Lactobacillus viridescens 2 ATCC 12706
Lactobacillus vitulinus ATCC 27783
Lactobacillus sp.
Lactococcus garviae NCDO 2156
Lactococcus lactis 1 ssp. *lactis* NCDO 2118
Lactococcus lactis 2
Lactococcus piscium
Lactococcus plantarum NCDO 1871
Lactococcus raffinolactis NCDO 2112
Leuconostoc amelobiosum
Leuconostoc carnosum
Leuconostoc citreum NCDO 1837
Leuconostoc cremoris DSM 20346
Leuconostoc fallax DSM 20189
Leuconostoc gelidum
Leuconostoc lactis 1 DSM 20202
Leuconostoc lactis 2 NCDO 533
Leuconostoc mesenteroides 1 DSM 20343
Leuconostoc mesenteroides 2 NCDO 523
Leuconostoc oenos 1 DSM 20252
Leuconostoc oenos 2 NCDO 1674
Leuconostoc paramesenteroides 1 DSM 20288
Leuconostoc paramesenteroides 2 NCDO 803
Leuconostoc pseudomesenteroides NCDO 768
Listeria grayi CIP 6818 (T)
Listeria innocua NCTC 11288 (T)
Listeria ivanovii NCTC 11846 (T)
Listeria monocytogenes 1
Listeria monocytogenes 2 NCTC 10357 (T)
Listeria murrayi NCTC 10812 (T)
Listeria seeligeri NCTC 11856 (T)
Listeria welshimeri NCTC 11857 (T)
Marinococcus halophilus NCIMB 2178 (T)
Megasphaera elsdenii
Mycoplasma agalactiae NCTC 10123
Mycoplasma arginini ATCC 23838
Mycoplasma arthritis ATCC 19611
Mycoplasma bovigenitalium ATCC 19852
Mycoplasma californicum ATCC 33461
Mycoplasma capricolum
Mycoplasma coragypsum
Mycoplasma elychniae ATCC 43707
Mycoplasma fermentans ATCC 19989
Mycoplasma flocculare ATCC 27716
Mycoplasma gallisepticum 1
Mycoplasma gallisepticum 2
Mycoplasma gallisepticum 3
Mycoplasma hominis 1 ATCC 23114
Mycoplasma hominis 2
Mycoplasma hyopneumoniae ATCC 27719
Mycoplasma hyorhinis ATCC 17981
Mycoplasma iowae 1 ATCC 33552
Mycoplasma iowae 2
Mycoplasma-like organism 1
Mycoplasma-like organism 2
Mycoplasma-like organism 3
Mycoplasma lipophilum ATCC 27104
Mycoplasma mobile ATCC 43663
Mycoplasma muris ATCC 33757
Mycoplasma mycoides
Mycoplasma neurolyticum ATCC 19988
Mycoplasma orale ATCC 23714
Mycoplasma pirum ATCC 25960
Mycoplasma pneumoniae ATCC 15531
Mycoplasma pulmonis ATCC 19612
Mycoplasma putrefaciens ATCC 15718
Mycoplasma salivarium ATCC 23064
Mycoplasma suis ATCC 33004
Mycoplasma sp. 1
Mycoplasma sp. 2
Mycoplasma sp. 3 ATCC 49193
Mycoplasma sp. 4 ATCC 49191
Oenothera hookeri MLO
Pectinatus cerevisiiphilus ATCC 29359
Pectinatus frisigensis ATCC 33332
Pediococcus acidilactici
Pediococcus pentosaceus
Peptococcus niger DSM 20475 (T)
Peptostreptococcus anaerobius
Planococcus citreus NCIMB 1493 (T)
Planococcus kocurii NCIMB 629
Quinella ovalis
Selenomonas lacticifex DSM 20757
Selenomonas ruminantium 1 subsp. *lactilytica* DSM 2872
Selenomonas ruminantium 2
Selenomonas ruminantium 3
Selenomonas sputigena ATCC 35185
Spiroplasma ATCC 43302
Spiroplasma apis ATCC 33834
Spiroplasma citri 1 ATCC 27556
Spiroplasma citri 2
Spiroplasma mirum ATCC 29335
Spiroplasma sp. 1 ATCC 43153
Spiroplasma sp. 2 ATCC 33827
Spiroplasma sp. 3 ATCC 33835
Spiroplasma sp. 4 ATCC 33825
Spiroplasma sp. 5 ATCC 43210
Spiroplasma sp. 6 ATCC 43525
Sporolactobacillus inulinus
Sporomusa paucivorans
Sporomusa termitida
Sporosarcina halophila NCIMB 2269
Sporosarcina ureae NCIB 9251

Table 1. *continued*

<i>Staphylococcus aureus</i> NCDO 949	<i>Atopobium rimae</i>
<i>Staphylococcus muscae</i> CCM 4175 (T)	<i>Bifidobacterium adolescentis</i>
<i>Staphylococcus schleiferi</i> DSM 4807 (T)	<i>Bifidobacterium asteroides</i>
<i>Staphylococcus sciuri</i>	<i>Bifidobacterium bifidum</i>
<i>Streptococcus acidominimus</i> NCDO 2025 (T)	<i>Bifidobacterium breve</i>
<i>Streptococcus agalactiae</i> NCDO 1348 (T)	<i>Bifidobacterium catenulatum</i>
<i>Streptococcus alactolytiens</i> NCDO 1091 (T)	<i>Bifidobacterium coryneforme</i>
<i>Streptococcus anginosus</i> NCTC 10713 (T)	<i>Bifidobacterium cuniculi</i>
<i>Streptococcus bovis</i> 1 NCDO 597 (T)	<i>Bifidobacterium dentium</i>
<i>Streptococcus bovis</i> 2	<i>Bifidobacterium globosum</i>
<i>Streptococcus canis</i> DSM 20715 (T)	<i>Bifidobacterium indicum</i>
<i>Streptococcus cecorum</i> NCDO 2674 (T)	<i>Bifidobacterium infantis</i>
<i>Streptococcus constellatus</i> NCTC 11325 (T)	<i>Bifidobacterium longum</i>
<i>Streptococcus cremoris</i>	<i>Bifidobacterium magnum</i>
<i>Streptococcus criae</i> NCDO 2772 (T)	<i>Bifidobacterium minimum</i>
<i>Streptococcus cricetus</i> NCDO 2720 (T)	<i>Bifidobacterium pseudolongum</i>
<i>Streptococcus downei</i> NCTC 11391 (T)	<i>Bifidobacterium suis</i>
<i>Streptococcus dysgalactiae</i> NCDO 2023 (T)	<i>Clavibacter xyli</i>
<i>Streptococcus equi</i> NCDO 2493 (T)	<i>Corynebacterium renale</i> ATCC 19412
<i>Streptococcus equinus</i> NCDO 1037 (T)	<i>Corynebacterium variabilis</i> NCIB 9455, NCDO 2097 (T)
<i>Streptococcus hanseii</i>	<i>Corynebacterium xerosis</i>
<i>Streptococcus hyointestinalis</i> DSM 20770 (T)	<i>Dermatophilus congolensis</i>
<i>Streptococcus intermedius</i> NCTC 11324 (T)	<i>Eubacterium suis</i> DSM 20639, ATCC 33144 (T)
<i>Streptococcus lactis</i>	<i>Faenia rectivirgula</i> ATCC 33515 (T)
<i>Streptococcus macacae</i> NCTC 11558 (T)	<i>Frankia</i> sp. 1
<i>Streptococcus mutans</i> NCTC 10449 (T)	<i>Frankia</i> sp. 2
<i>Streptococcus oralis</i> NCTC 11427 (T)	<i>Frankia</i> sp. 3
<i>Streptococcus parasanguis</i> NCTC 7863 (T)	<i>Frankia</i> sp. 4
<i>Streptococcus parauberis</i> NCDO 651	<i>Frankia</i> sp. 5
<i>Streptococcus pleomorphus</i> ATCC 29734	<i>Fusobacterium prausnitzii</i>
<i>Streptococcus pneumoniae</i> NCTC 7465 (T)	<i>Gardnerella vaginalis</i>
<i>Streptococcus porcicus</i> NCDO 600 (T)	<i>Gordona terrae</i> DSM 43249
<i>Streptococcus pyogenes</i> NCDO 2381 (T)	<i>Kibdelosporangium aridum</i> ATCC 39323
<i>Streptococcus rattus</i> NCDO 2723 (T)	<i>Kitasatosporia griseola</i> NRRL B-16229
<i>Streptococcus saccharolyticus</i> NCDO 2594	<i>Kitasatosporia phosalacinea</i> NRRL B-16230
<i>Streptococcus salivarius</i> 1 NCDO 1779 (T)	<i>Kitasatosporia setae</i> NRRL B-16185
<i>Streptococcus salivarius</i> 2	<i>Lactobacillus minutus</i>
<i>Streptococcus sanguis</i> NCTC 7863	<i>Micrococcus luteus</i>
<i>Streptococcus sobrinus</i> DSM 20742 (T)	<i>Mobiluncus curtisii</i> ATCC 35421
<i>Streptococcus suis</i> NCTC 10237 (T)	<i>Mobiluncus mulieris</i> ATCC 35423
<i>Streptococcus thermophilus</i> NCDO 573 (T)	<i>Mycobacterium aichiense</i> ATCC 27280
<i>Streptococcus uberis</i> NCDO 643	<i>Mycobacterium asiaticum</i> 1 ATCC 25276
<i>Streptococcus vestibularis</i> NCTC 12166 (T)	<i>Mycobacterium asiaticum</i> 2 ATCC 25276
<i>Syntrophomonas wolfei</i>	<i>Mycobacterium aurum</i> 1 ATCC 23366
<i>Syntrophospora bryantii</i>	<i>Mycobacterium aurum</i> 2 ATCC 23366
<i>Ureaplasma urealyticum</i> NCTC 10177	<i>Mycobacterium avium</i> 1
<i>Vagococcus fluvialis</i> NCDO 2497	<i>Mycobacterium avium</i> 2
<i>Vagococcus salmoninarum</i>	<i>Mycobacterium avium</i> 3 DSM 43216
<i>Western aster yellow</i> MLO isolated from celery	<i>Mycobacterium avium</i> 4
<i>Zymophilus paucivorans</i> DSM 20756	<i>Mycobacterium avium</i> 5
GRAM POSITIVES AND RELATIVES, HIGH G+C	
<i>Actinomyces bovis</i> 1 DSM 43014	<i>Mycobacterium avium</i> 6
<i>Actinomyces bovis</i> 2 DSM 43014	<i>Mycobacterium avium</i> 7
<i>Actinomyces israelii</i> 1 DSM 43020	<i>Mycobacterium avium</i> 8
<i>Actinomyces israelii</i> 2 DSM 43020	<i>Mycobacterium avium</i> 9
<i>Actinomyces naeslundii</i> 1 DSM 43013	<i>Mycobacterium avium</i> 10
<i>Actinomyces naeslundii</i> 2 DSM 43013	<i>Mycobacterium bovis</i> 1
<i>Actinomyces odontolyticus</i> 1 DSM 43331	<i>Mycobacterium bovis</i> 2
<i>Actinomyces odontolyticus</i> 2 DSM 43331	<i>Mycobacterium chelonae</i> ATCC 14472
<i>Actinomyces pyogenes</i> ATCC 19411	<i>Mycobacterium chelonae</i> ATCC 19977
<i>Actinomyces viscosus</i> 1 DSM 43027	<i>Mycobacterium chitae</i> 1 ATCC 19627
<i>Actinomyces viscosus</i> 2 DSM 43027	<i>Mycobacterium chitae</i> 2
<i>Actinopolyspora halophila</i> ATCC 279	<i>Mycobacterium chitae</i> 3 ATCC 19627
<i>Aeromicrobium erythreum</i> NRRL B-3381 (T)	<i>Mycobacterium chitae</i> 4 ATCC 19627
<i>Amycolata autotrophica</i> DSM 43210	<i>Mycobacterium chubuense</i> ATCC 27278
<i>Amycolata nitrificans</i> DSM new	<i>Mycobacterium confluens</i>
<i>Amycolata petroleophila</i> DSM new	<i>Mycobacterium cookii</i> ATCC 49103, DSM 43922 (T)
<i>Amycolatopsis azurae</i> NRRL 11412	<i>Mycobacterium diernhoferi</i> ATCC 19340
<i>Amycolatopsis fastidiosa</i> ATCC 31181	<i>Mycobacterium fallax</i> ATCC 35219
<i>Amycolatopsis methanolica</i> NCIB 11946 (T)	<i>Mycobacterium farcinogenes</i> DSM 43294
<i>Arthrobacter globiformis</i>	<i>Mycobacterium flavescens</i> 1 ATCC 14474
<i>Arthrobacter simplex</i> ATCC 6946	<i>Mycobacterium flavescens</i> 2 ATCC 14474
<i>Arthrobacter</i> sp.	<i>Mycobacterium fortuitum</i> ATCC 6841 (T)
<i>Atopobium parvulum</i>	<i>Mycobacterium gadium</i> 1
	<i>Mycobacterium gadium</i> 2 ATCC 27726
	<i>Mycobacterium gastris</i> ATCC 15754

- Mycobacterium gilvum* ATCC 43909
Mycobacterium gordonae 1 ATCC 14470
Mycobacterium gordonae 2 ATCC 14470
Mycobacterium intracellulare 1 ATCC 15985
Mycobacterium intracellulare 2
Mycobacterium intracellulare 3
Mycobacterium intracellulare 4
Mycobacterium intracellulare 5
Mycobacterium intracellulare 6
Mycobacterium kansasii 1 DSM 43224
Mycobacterium kansasii 2 ATCC 12478
Mycobacterium komossense ATCC 33013
Mycobacterium leprae 1
Mycobacterium leprae 2
Mycobacterium leprae 3
Mycobacterium madagascariense
Mycobacterium malmoense 1 ATCC 29571
Mycobacterium malmoense 2
Mycobacterium marinum
Mycobacterium neoaurum ATCC 25795
Mycobacterium nonchromogenicum 1 ATCC 19530
Mycobacterium nonchromogenicum 2 ATCC 19530
Mycobacterium obuense ATCC 27023
Mycobacterium paratuberculosis 1
Mycobacterium paratuberculosis 2
Mycobacterium paratuberculosis 3
Mycobacterium paratuberculosis 4
Mycobacterium paratuberculosis 5
Mycobacterium paratuberculosis 6
Mycobacterium paratuberculosis 7
Mycobacterium paratuberculosis 8
Mycobacterium paratuberculosis 9 ATCC 19698
Mycobacterium phlei ATCC 11758
Mycobacterium scrofulaceum ATCC 19981
Mycobacterium senegalense ATCC 35796
Mycobacterium simiae ATCC 25275
Mycobacterium smegmatis ATCC 14468
Mycobacterium sphagni ATCC 33026
Mycobacterium szulgai 1 ATCC 25799
Mycobacterium szulgai 2
Mycobacterium terrae 1 ATCC 15755
Mycobacterium terrae 2 ATCC 15755
Mycobacterium thermoresistibile 1 ATCC 19527
Mycobacterium thermoresistibile 2 ATCC 19527
Mycobacterium triviale ATCC 23292
Mycobacterium tuberculosis 1
Mycobacterium tuberculosis 2
Mycobacterium tuberculosis 3 NCTC 7416
Mycobacterium ulcerans
Mycobacterium vaccae ATCC 15483
Mycobacterium xenopi 1 ATCC 19250
Mycobacterium xenopi 2 ATCC 19250
Mycobacterium sp. 1
Mycobacterium sp. 2
Mycobacterium sp. 3
Nocardia asteroides 1 DSM 43005
Nocardia asteroides 2 ATCC 3306
Nocardia otitidis-caviarum
Nocardioides albus DSM 43109
Nocardioides fastidiosa NCIB 12713 (T)
Nocardioides jensenii DSM 29641
Nocardioides luteus NCIB 11455
Nocardioides simplex 1 NCIB 8929
Nocardioides simplex 2 NCIB 8929 (T)
Propionibacterium acidipropionici DSM 20272
Propionibacterium acnes 1 DSM 1897
Propionibacterium acnes 2
Propionibacterium freudenreichii DSM 20271
Propionibacterium jensenii DSM 20535
Propionibacterium propionicus DSM 43307
Propionibacterium thoenii DSM 20276
Pseudonocardia thermophila 1 ATCC 19285 (T)
Pseudonocardia thermophila 2 ATCC 19285 (T)
Renibacterium salmoninarum ATCC 33209 (T)
Rhodococcus equi Equine lung
Rhodococcus erythropolis DSM 43188
Rhodococcus fascians DSM 20131
Rothia dentocariosa
Saccharomonospora viridis ATCC 15386
Saccharopolyspora erythraea NRRL 2338
Saccharopolyspora hirsuta 1 ATCC 27875 (T)
Saccharopolyspora hirsuta 2
Saccharopolyspora hordei
Saccharothrix australiensis ATCC 31947
Streptomyces albus DSM 40313, ISP 5313 (T)
Streptomyces ambofaciens ATCC 23877
Streptomyces brasiliensis DSM 43159 (T)
Streptomyces coelicolor 1
Streptomyces coelicolor 2
Streptomyces diastaticus DSM 40496, ISP 5496 (T)
Streptomyces griseus subsp. *griseus* ATCC 10137
Streptomyces lavendulae DSM 2014, ISP 5069 (T)
Streptomyces lividans
Streptomyces purpureus DSM 43460 (T)
Streptoverticillium abikoense DSM 40831 (T)
Streptoverticillium baldacii
Streptoverticillium cinnamoneum spp. *azacolum*
Streptoverticillium cinnamoneum spp. *cinnamoneum*
Streptoverticillium ladakanum DSM 40587 (T)
Streptoverticillium luteoreticuli
Streptoverticillium olivoreticuli ssp. *cellulophilum*
Streptoverticillium salmonis
Terrabacter tumescens NCIB 8914
Tropheryma whippelii
Tsukamurella aurantiacus NCTC 10741
Tsukamurella paurometabolum 1 DSM 20162, NCTC 10741
Tsukamurella paurometabolum 2 NCTC 10741
- GREEN NON SULFUR**
- Chloroflexus aurantiacus*
Herpetosiphon aurantiacus ATCC 23779
Sphaerobacter thermophilus DSM 20745 (T)
Thermomicrobium roseum ATCC 27502
- RADIORESISTANT MICROCOCCI AND RELATIVES**
- Deinococcus radiodurans* UWO 298
Thermus aquaticus 1
Thermus aquaticus 2
Thermus aquaticus 3 ATCC 27978
Thermus filiformis 1 ATCC 43280
Thermus filiformis 2
Thermus flavus 1 ATCC 33923
Thermus flavus 2
Thermus ruber 1 ATCC 35948
Thermus ruber 2
Thermus thermophilus 1
Thermus thermophilus 2 ATCC 27634
Thermus thermophilus 3 ATCC 27634
Thermus thermophilus 4
Thermus sp. 1
Thermus sp. 2
Thermus sp. 3
Thermus sp. 4
Thermus sp. 5
Thermus sp. 6
Thermus sp. 7
Thermus sp. 8
Thermus sp. 9
Thermus sp. 10
- THERMOTOGALES**
- Fervidobacterium nodosum* ATCC 35602
Fervidobacterium islandicum DSM 5733 (T)
Thermosiphon africanus
Thermotoga maritima DSM 3109
- PLANCTOMYCES AND RELATIVES**
- Gemmata obscuriglobus* 1 UQM 2246
Gemmata obscuriglobus 2 UQM 2246
Isosphaera pallida
Pirellula marina DSM 3645
Planctomyces limnophilus ATCC 43296
Planctomyces maris ATCC 29209 (T)
Planctomyces staleyii

Table 1. *continued*

UNCERTAIN AFFILIATION	<i>Antilocapra americana</i>
<i>Aquifex pyrophilus</i>	<i>Atelerix albiventris</i>
<i>Flexistipes sinusarabici</i> DSM 4947	<i>Balaenoptera physalus</i>
<i>Haloanaerobium praevalens</i>	<i>Bathergus janetta</i>
<i>Leptospirillum</i> sp. DSM 2391	<i>Bathergus suillus</i>
<i>Sporohalobacter lortetii</i>	<i>Blarina brevicauda</i>
<i>Synergistis jonesii</i>	<i>Bos taurus</i>
PLASTIDS	<i>Boselaphus tragocamelus</i>
PLANTAE	<i>Capra hircus</i>
BRYOPHYTA	<i>Cephalophus maxwelli</i>
MARCHANTIOPSIDA	<i>Cervus unicolor</i>
<i>Marchantia polymorpha</i>	<i>Cryptomys hottentotus</i> 1
MAGNOLIOPHYTA	<i>Cryptomys hottentotus</i> 2
LILLOPSIDA	<i>Cryptomys hottentotus damarensis</i>
<i>Oryza sativa</i>	<i>Damaliscus dorcas</i>
<i>Zea mays</i>	<i>Gazella thomsoni</i>
MAGNOLIOPSIDA	<i>Georchus capensis</i>
<i>Conopholis americana</i>	<i>Gorilla gorilla</i>
<i>Epifagus virginiana</i>	<i>Heliophobius argenteocinereus</i>
<i>Glycine max</i>	<i>Heterocephalus glaber</i>
<i>Nicotiana plumbaginifolia</i>	<i>Homo sapiens</i> 1
<i>Nicotiana tabacum</i> 1	<i>Homo sapiens</i> 2
<i>Nicotiana tabacum</i> 2	<i>Hydropotes inermis</i>
<i>Pisum sativum</i> 1	<i>Kobus ellipsiprymnus</i>
<i>Pisum sativum</i> 2	<i>Madoqua kirki</i>
PROTISTA	<i>Muntiacus reevesi</i>
ASSEMBLAGE CHLOROBIONTS	<i>Mus musculus</i>
CHLOROPHYTA	<i>Odocoileus virginianus</i>
<i>Chlamydomonas eugametos</i>	<i>Oryx gazella</i>
<i>Chlamydomonas moewusii</i>	<i>Pan paniscus</i>
<i>Chlamydomonas reinhardtii</i>	<i>Pan troglodytes</i>
<i>Chlorella ellipsoidea</i>	<i>Petromus typicus</i>
<i>Chlorella kessleri</i>	<i>Phoca vitulina</i>
<i>Chlorella mirabilis</i>	<i>Pongo pigmaeus</i>
<i>Chlorella protothecoides</i>	<i>Rattus norvegicus</i> 1
<i>Chlorella sorokiniana</i>	<i>Rattus norvegicus</i> 2
<i>Chlorella vulgaris</i>	<i>Thryonomys swinderianus</i>
ASSEMBLAGE CHROMOBIONTS	<i>Tragelaphus imberbis</i>
CHRYSOPHYTA	<i>Tragulus napu</i>
<i>Ochromonas danica</i>	AVES
<i>Olisthodiscus luteus</i>	<i>Coturnix japonica</i>
HAPTOPHYTA	<i>Gallus gallus</i>
<i>Ochrosphaera</i> spec.	AMPHIBIA
PHAEOPHYTA	<i>Rana catesbeiana</i>
<i>Pylaiella littoralis</i> 1	<i>Xenopus laevis</i>
ASSEMBLAGE CRYPTOMONADS	OSTEICHTYES
CRYPTOPHYTA	<i>Crossostoma lacustre</i>
<i>Cryptomonas phi</i>	<i>Cyprinus carpio</i>
<i>Pyrenomonas salina</i>	ECHINODERMATA
ASSEMBLAGE EUGLENOZOA	ECHINOIDEA
EUGLENOPHYTA	<i>Paracentrotus lividus</i>
<i>Astasia longa</i>	<i>Strongylocentrotus purpuratus</i>
<i>Euglena gracilis</i>	ARTHROPODA
ASSEMBLAGE RHODOPHYTES	INSECTA
RHODOPHYTA	<i>Apis mellifera ligustica</i>
<i>Anthithamnion</i> sp.	<i>Drosophila virilis</i>
<i>Cyanidium caldarium</i>	<i>Drosophila yakuba</i>
MITOCHONDRIA	NEMATODA
ANIMALIA	SECERNENTEA
CHORDATA	<i>Ascaris suum</i>
VERTEBRATA	<i>Caenorhabditis elegans</i>
MAMMALIA	PLANTAE
<i>Aepyceros melampus</i>	BRYOPHYTA
<i>Amblysomus hottentotus</i>	MARCHANTIOPSIDA
	<i>Marchantia polymorpha</i>
	MAGNOLIOPHYTA
	LILLOPSIDA
	<i>Secale cereale</i>
	<i>Triticum aestivum</i>

Zea diploperennis
Zea mays 1
Zea mays 2

MAGNOLIOPSIDA

Glycine max
Lupinus luteus
Oenothera sp.

FUNGI

ASCOMYCOTINA

HEMIASCOMYCETES

Saccharomyces cerevisiae 1
Saccharomyces cerevisiae 2
Saccharomyces cerevisiae 3
Saccharomyces cerevisiae 4
Saccharomyces cerevisiae 5

EUASCOMYCETES

Aspergillus nidulans
Podospora anserina

UNCERTAIN AFFILIATION

Schizosaccharomyces pombe

PROTISTA

ASSEMBLAGE CHLOROBIONTS

CHLOROPHYTA

Chlamydomonas reinhardtii
Prototheca wickerhamii

ASSEMBLAGE CILIATES

CILIOPHORA

Paramecium aurelia
Paramecium primaurelia
Paramecium tetraurelia
Tetrahymena pyriformis 1
Tetrahymena pyriformis 2

ASSEMBLAGE EUGLENOZOA

KINETOPLASTIDS

Crithidia fasciculata
Leishmania tarentolae
Leptomonas sp.
Trypanosoma brucei

ASSEMBLAGE SPOROZOA

APICOMPLEXA

Plasmodium falciparum 1
Plasmodium falciparum 2

(a) Some species names are listed several times followed by a sequential number. This means that the SSU rRNA sequence has been determined several times, usually by different authors. The sequences are not necessarily the same since they may have been determined for different varieties or strains of a species, or for different genes of the same organism. The systematics followed for the three domains are mentioned in the text. Plastidial and mitochondrial structures are listed according to the systematics followed for the host organism. In the case of Archaea and Bacteria, the species name is followed by the culture collection name and number if specified by the author. This number is followed by (T) if it is a type species. Abbreviations of culture collection names can be found in the catalogs of the American Type Culture Collection (ATCC), Deutsche Sammlung von Mikroorganismen (DSM), and Laboratorium voor Microbiologie Universiteit Gent (LMG). The assignment of the archaeal and bacterial species to taxa is based on the tree shown in outline in Fig. 1. These taxa correspond to the divisions and subdivisions distinguished by Woese and coworkers (10–12), except for the bacterial genera *Fibrobacter* and *Fusobacterium*, which form separate clusters and therefore are listed as separate taxa. The taxon of Gram positive bacteria of low GC contents and relatives comprises a number of genera with gram negative cell walls: *Megasphaera*, *Pectinatus*, *Selenomonas*, *Sporomusa*, and *Zymophilus*. For the Archaea, the classification is slightly different from that followed by Olsen and Woese (12), as explained in the text.

(b) Most of the species listed under the heading 'Proteobacteria gamma*' are attributed to the Proteobacteria γ group by Woese (11), although they cluster with the Proteobacteria β in the tree of Fig. 1. Exceptions are *Xanthomonas maltophilia* and *Xylella fastidiosa* which belong to the Proteobacteria β group according to the same author (11).

Table 2. Helix occupancy in eukaryotic SSU rRNAs.

Taxon & Species ^a	Helices ^b															
	E8 1	E10 1	2	E23 1	2	3	4	5	6	7	8	9	10	11	12	E45 1
Insecta	—	*	—	*	*	*	*	*	*	*	*	*	—	—	—	—
Platyhelminthes	—	*	—	*	*	*	*	*	*	*	*	*	—	—	—	—
<i>Schizosaccharomyces pombe</i> (Ascomycotina)	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
<i>Euplotes aediculatus</i> (Ciliophora)	*	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
<i>Euglena gracilis</i> (Euglenophyta)	*	*	*	*	*	*	*	*	*	*	*	*	—	—	*	*
<i>Bodo caudatus</i> (Kinetoplastidea)	*	*	—	*	*	—	—	*	*	*	*	*	*	—	—	*
<i>Tritrichomonas foetus</i> (Kinetoplastidea)	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
<i>Trypanosoma cruzi</i> (Kinetoplastidea)	*	*	—	*	*	—	—	*	*	*	*	*	*	*	*	*
Other Kinetoplastidea	*	*	—	*	*	—	—	*	*	*	*	*	*	—	*	*
<i>Blastocladia emersonii</i> (Chytridiomycota)	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
<i>Encephalitozoon cuniculi</i> (Microsporidia)	—	—	—	—	—	—	—	—	—	—	*	*	—	—	—	—
<i>Vairimorpha necatrix</i> (Microsporidia)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Giardia</i> (Polymastigotes)	—	—	—	—	—	—	—	—	*	*	*	*	—	—	—	—
<i>Acanthamoeba castellanii</i> (Amoebozoa)	—	*	—	*	*	—	*	*	*	*	*	*	—	—	—	*
<i>Naegleria gruberi</i> (Amoebozoa)	—	*	*	*	*	—	*	*	*	*	*	*	—	—	—	*
Other Amoebozoa	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
<i>Physarum polycephalum</i> (Eumycetozoa)	*	*	—	*	*	—	*	*	*	*	*	*	—	—	—	—
<i>Babesia</i> (Apicomplexa)	—	*	—	—	*	—	—	*	*	*	*	*	—	—	—	—
<i>Plasmodium</i> (Apicomplexa)	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	*
Other Eukarya	—	*	—	*	*	—	—	*	*	*	*	*	—	—	—	—

(a) In the case of the genera *Giardia*, *Babesia*, and *Plasmodium*, the helix occupancy applies to all species of the genus.
 (b) The presence of a helix is indicated by an asterisk. Only eukaryote-specific helices are listed since universal helices are present in all known eukaryotic SSU rRNAs except those of *Vairimorpha necatrix*, which lacks helices 10, 11, 43, and 46 and of *Encephalitozoon cuniculi*, which lacks helices 11, 18, 43, and 46. The structure of the SSU rRNA of the insect *Acyrtosiphon pisum* in area V4 (helices E23-n), which is exceptionally large in this species, is not yet known.

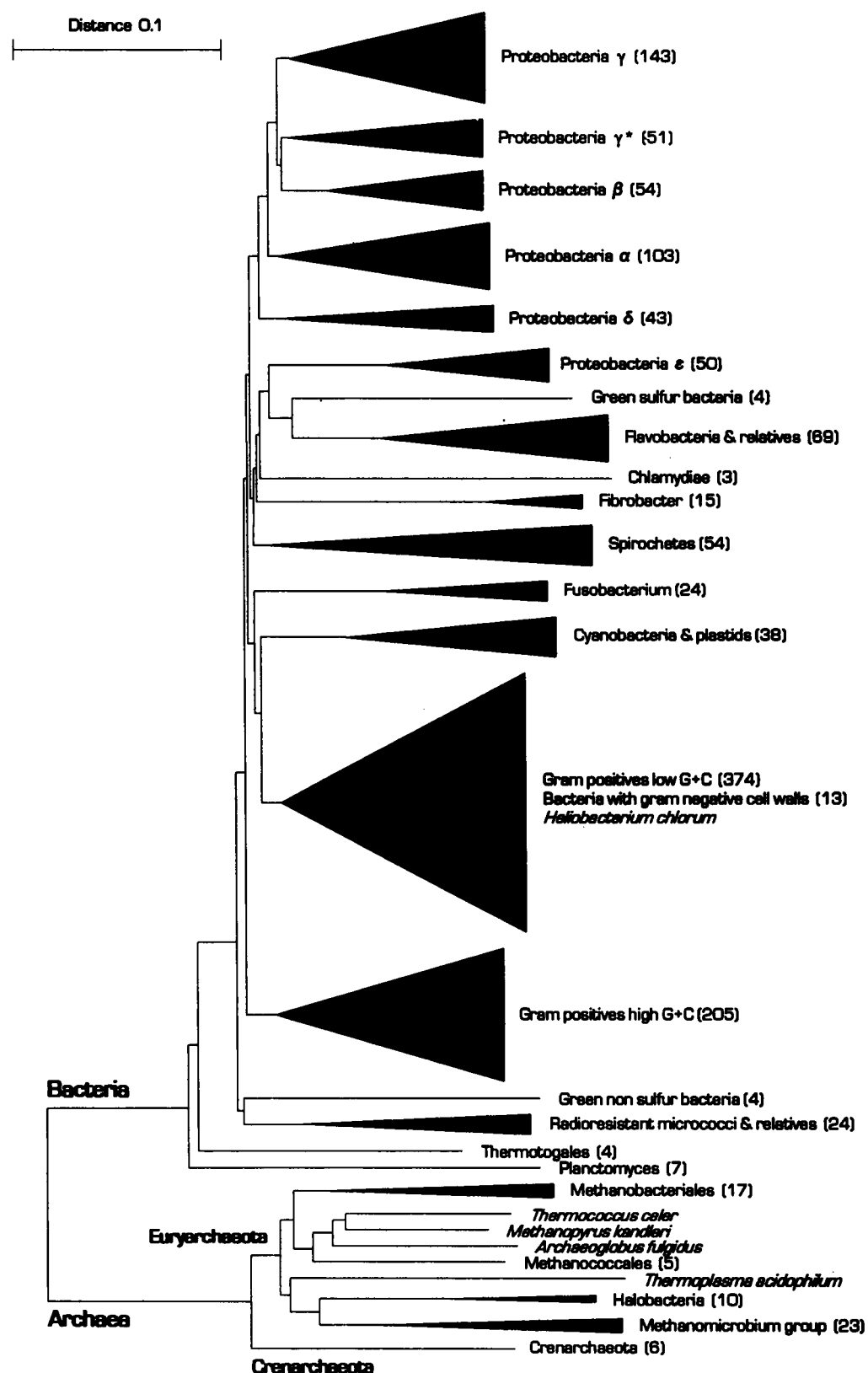


Figure 1. Evolutionary tree reconstructed from archaeal, bacterial and plastidial SSU rRNA sequences. The tree was constructed as described in the text from a total of 1348 SSU rRNA sequences. Clusters distinguishable in the tree are simplified to isosceles triangles with a height approximately equal to the average distance separating the terminal nodes from the deepest branching point within the cluster, and a base proportional to the number of sequences composing it, mentioned in brackets after the taxon name. If a taxon is represented by a single sequence, the species name is mentioned in italics. Each cluster corresponds to a taxon listed in Table 1. The cluster labeled Proteobacteria γ^* is in fact more closely related to the Proteobacteria β than to the Proteobacteria γ in the present tree. However, its position between the latter two clusters is not stable and it consists mainly of species classified as Proteobacteria γ by Woese (11) (see also footnote b to Table 1). The scale on top measures evolutionary distance expressed in substitutions per nucleotide.

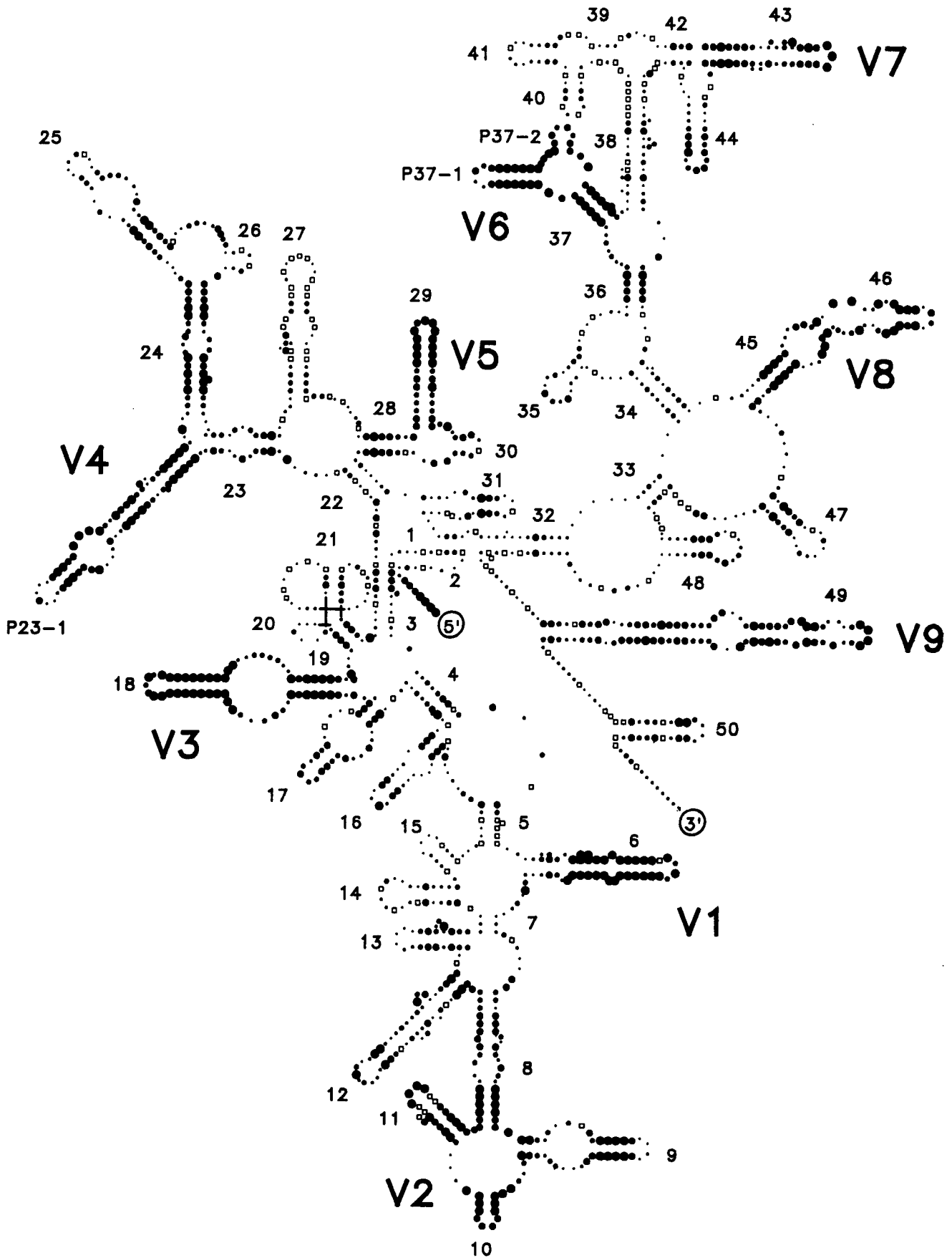


Figure 2. Secondary structure model for prokaryotic SSU rRNAs. Sites are divided into five equally numerous categories of increasing variability, indicated by full circles of increasing diameter. Sites that are invariant among presently known sequences are indicated as hollow squares. Areas containing the most variable sites are labeled V1 to V9. The helix numbering system is explained in the text. Helices P37-1 and P37-2 are absent in archaeal SSU rRNAs.

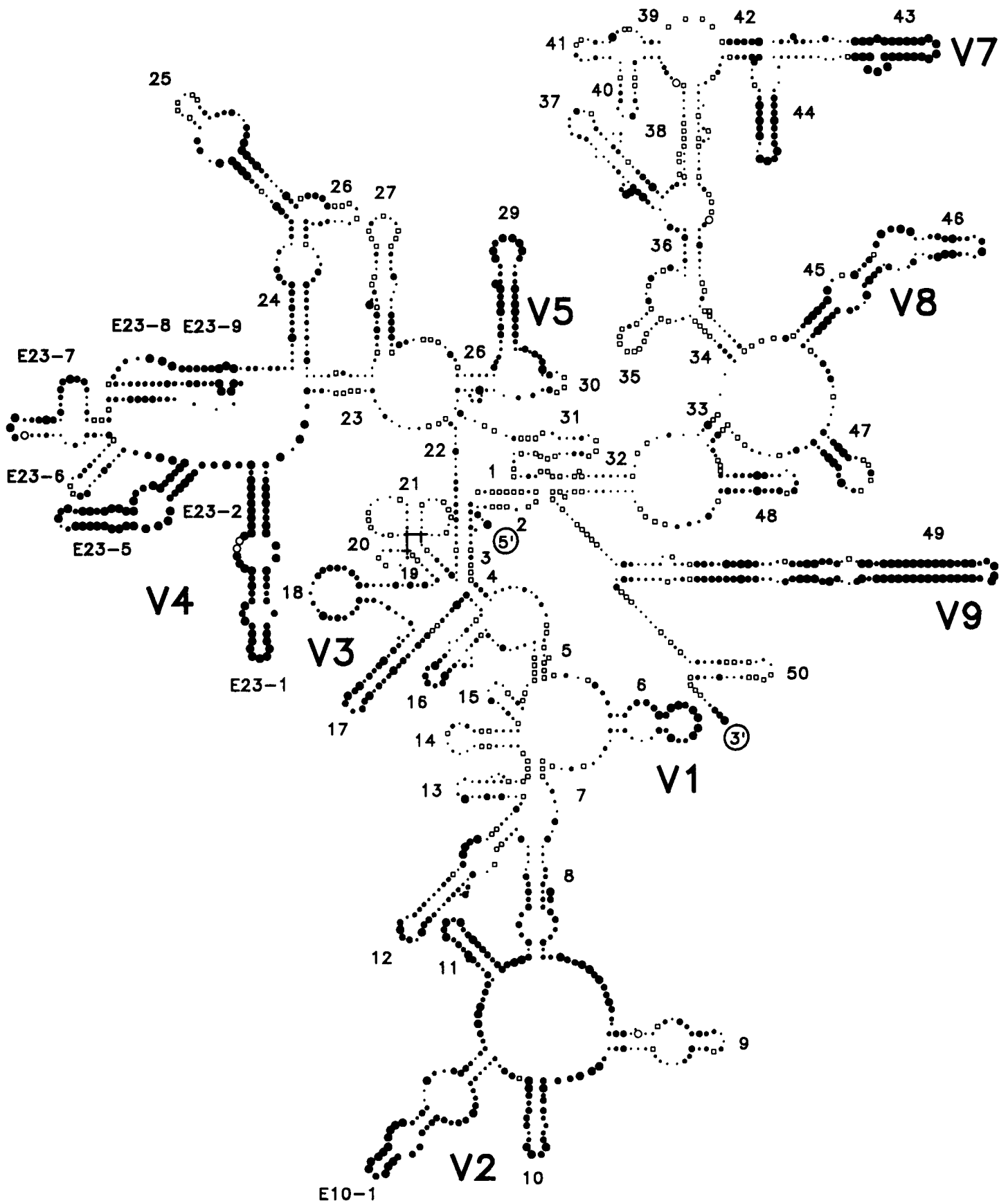


Figure 3. Secondary structure model for eukaryotic SSU rRNAs. Conventions are as in Fig. 2. The shape of the model is based on *Saccharomyces cerevisiae* SSU rRNA, and hollow circles represent nucleotides deleted in most other eukaryotic SSU rRNAs. The area corresponding to V6 in prokaryotic SSU rRNAs is more conserved among eukaryotic SSU rRNAs.

Escherichia coli

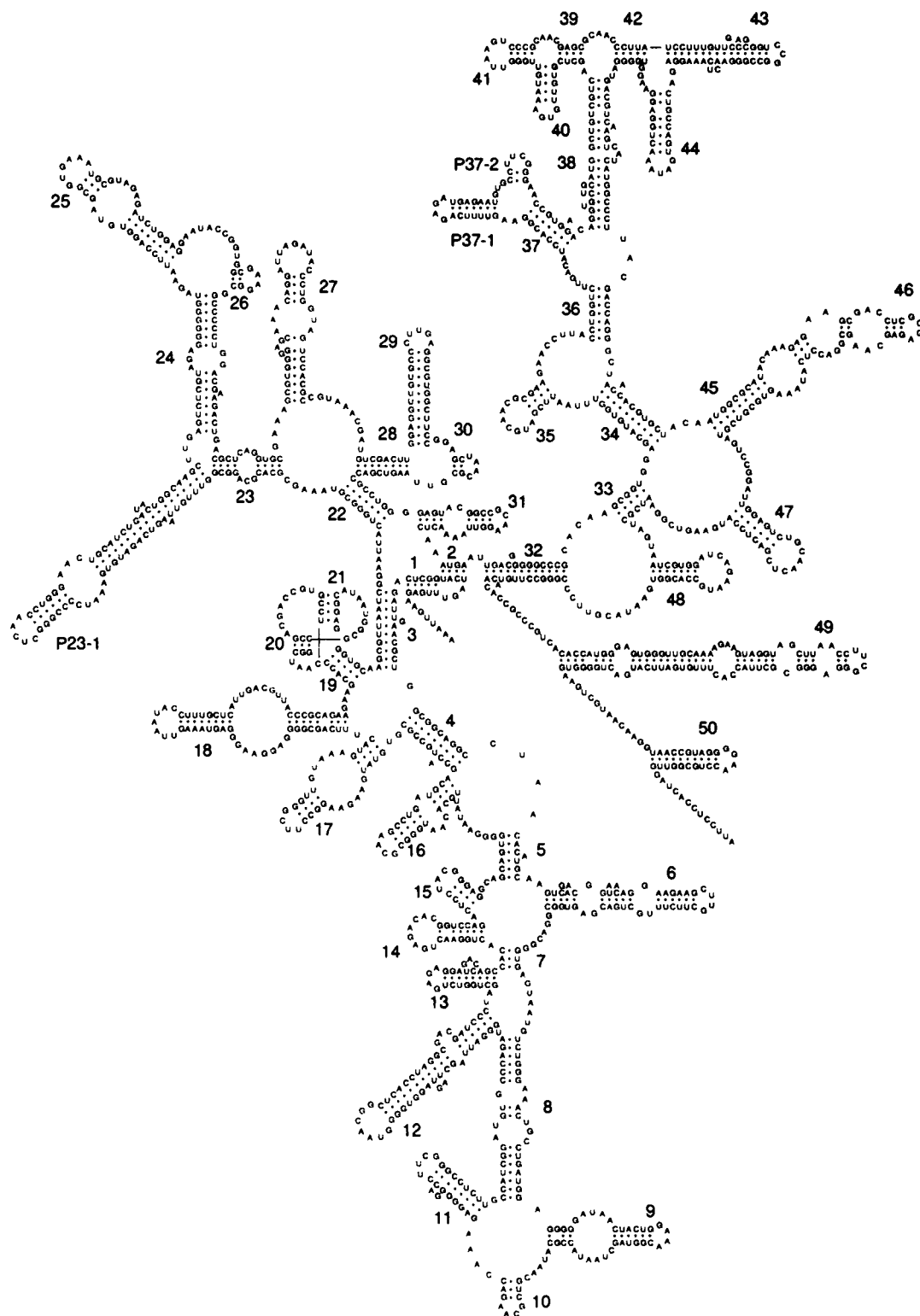


Figure 4. Secondary structure model for SSU rRNA of the bacterium *Escherichia coli*.

Palmaria palmata

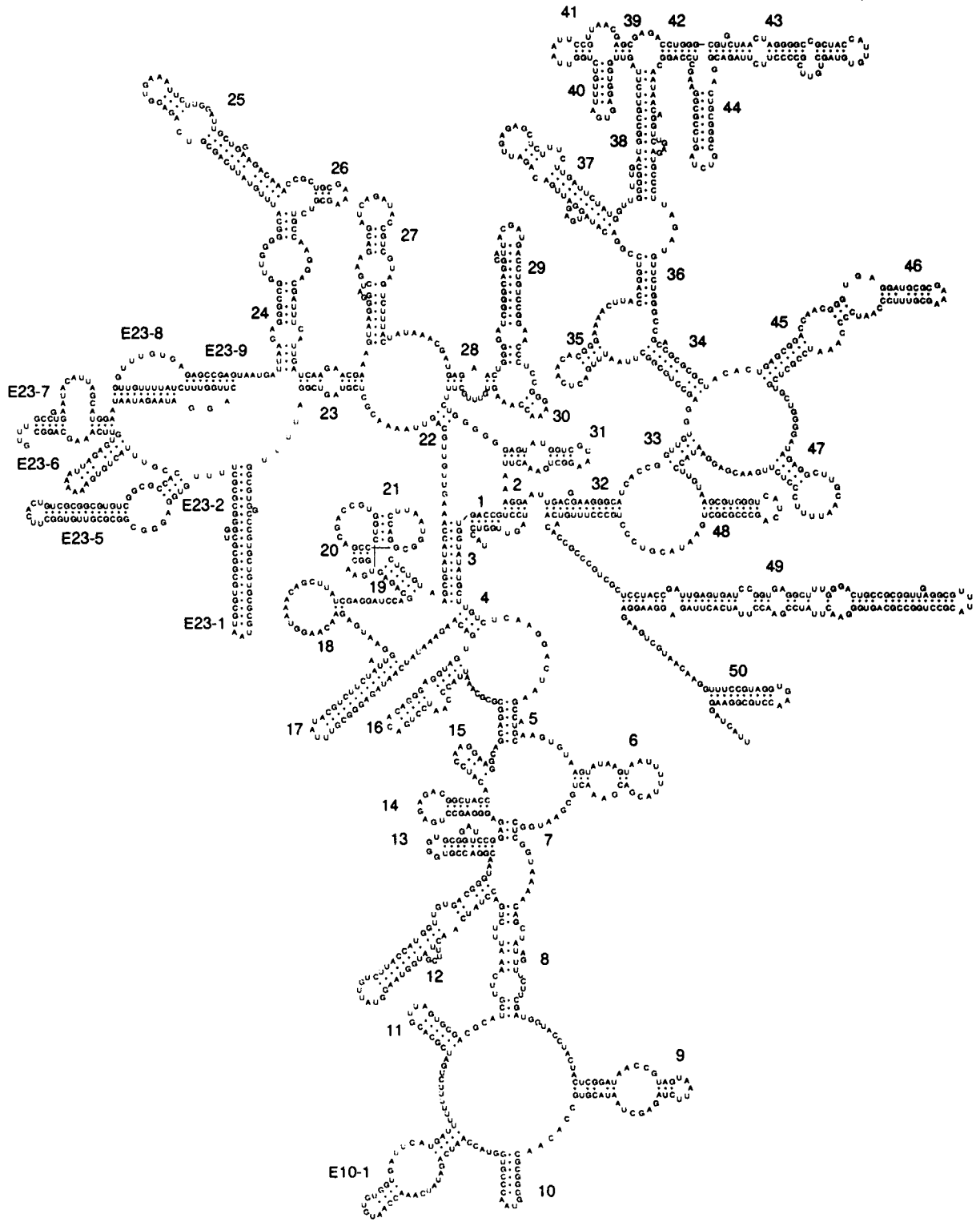


Figure 6. Secondary structure model for SSU rRNA of the red alga *Palmaria palmata*.

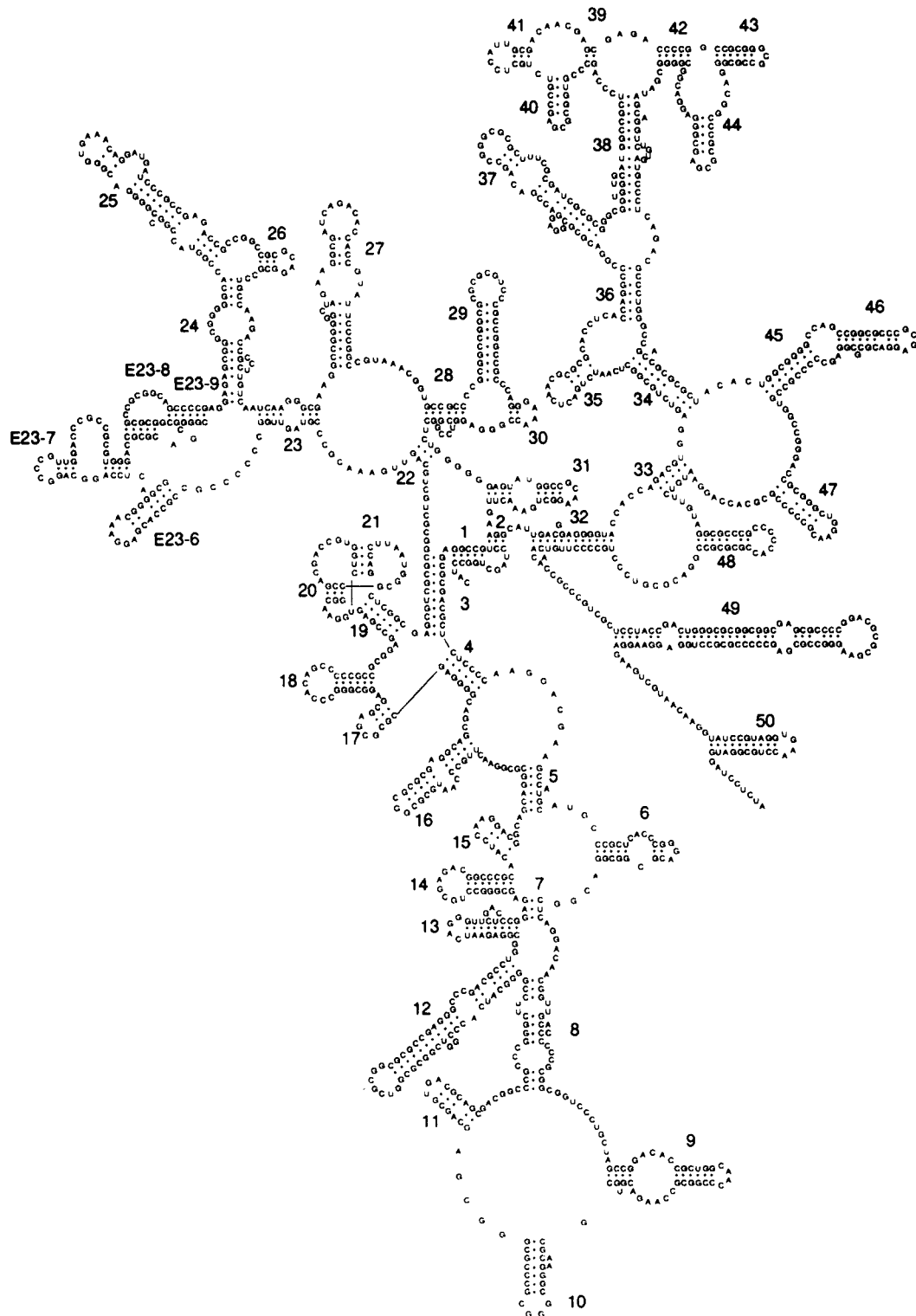


Figure 7. Secondary structure model for SSU rRNA of the polymastigote *Giardia duodenalis*.

Homo sapiens mitochondrion

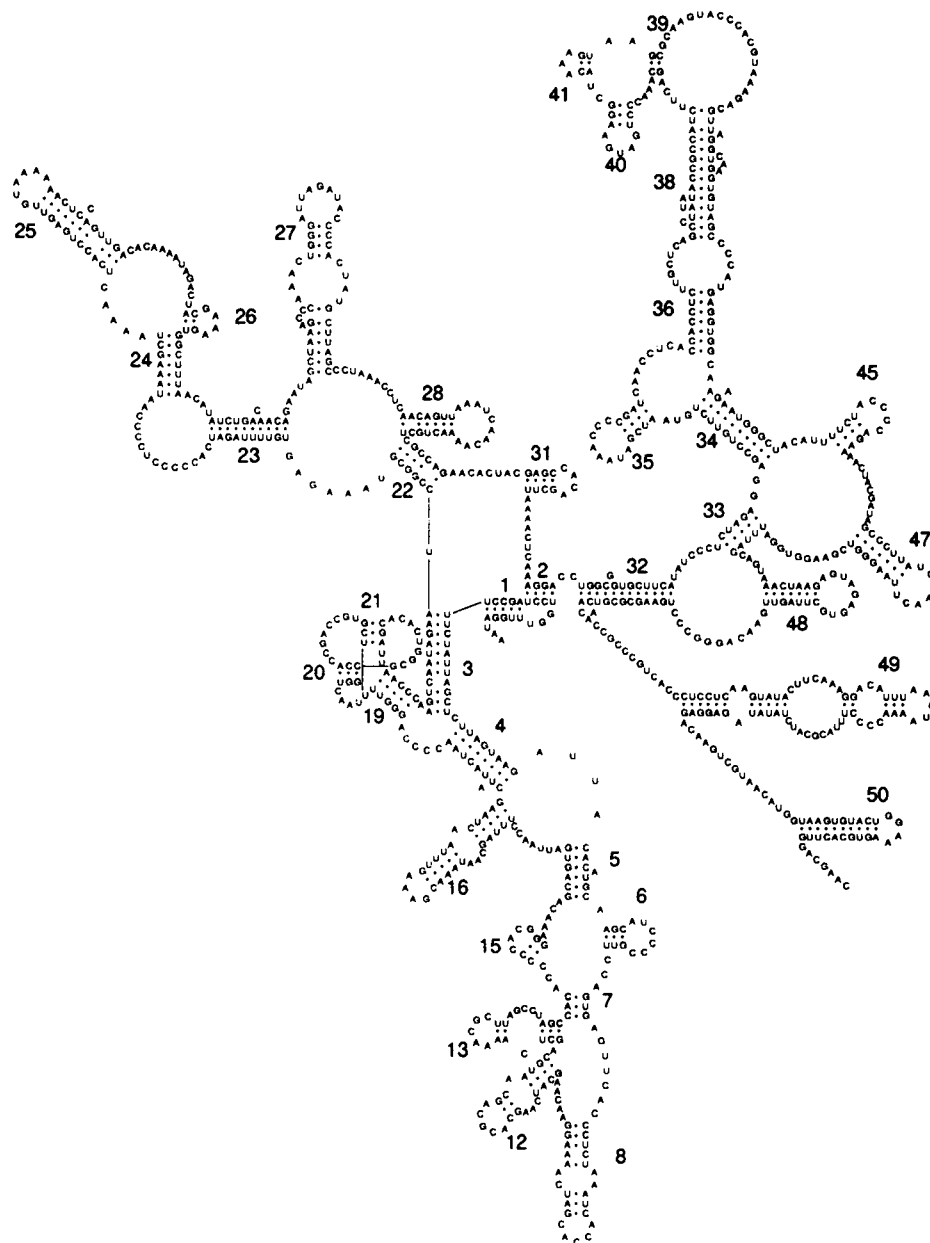


Figure 8. Secondary structure model for SSU rRNA of *Homo sapiens* mitochondrion.