

# Mucin-bacterial interactions in the human oral cavity and digestive tract

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Mucins are a family of heavily glycosylated proteins that are the major organic components of the mucus layer, the protective layer covering the epithelial cells in many human and animal organs, including the entire gastro-intestinal tract. Microbes that can associate with mucins benefit from this interaction since they can get available nutrients, experience physico-chemical protection and adhere, resulting an increased residence time. Mucin-degrading microorganisms, which often are found in consortia, have not been extensively characterized as mucins are high molecular weight glycoproteins that are hard to study because of their size, complexity and heterogeneity. The purpose of this review is to discuss how advances in mucus and mucin research, and insight in the microbial ecology promoted our understanding of mucin degradation. Recent insight is presented in mucin structure and organization, the micro-organisms known to use mucin as growth substrate, with a specific attention on *Akkermansia muciniphila*, and the molecular basis of microbial mucin degradation owing to availability of genome sequences.

## Supplementary Material

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1 **Table S1.** Interaction of human salivary mucins (Muc5AC and MUC7) with micro-organisms

2

3

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<b>Microorganism</b>	<b>MUC5B</b>	<b>MUC7</b>	<b>MUC5B/MUC7</b>	<b>References</b>
<i>Actinobacillus</i>				
<i>actinomycetemcomitans</i>		+		178
<i>Actinomyces naeslundii</i>		+		179
<i>Fusobacterium nucleatum</i>		+		179
<i>Pseudomonas aeruginosa</i>		+		180, 181
<i>Staphylococcus aureus</i>		+		180
<i>Streptococcus gordonii</i>		+		31, 179, 182, 183
<i>Streptococcus mutant</i>		+		184, 185
<i>Streptococcus oralis</i>		+		179, 182
<i>Streptococcus salivarius</i>		+		186
<i>Streptococcus sanguinis</i>		+		179, 182, 187
<i>Helicobacter pylori</i>	+		+	188-190
<i>Streptococcus rattus</i>			+	191
<i>Escherichia coli</i> (type 1 <i>fimbriated</i> )			+	181
<i>Hemophilus parainfluenzae</i>	+			192
Human immunodeficiency virus type 1			+	193, 194
<i>Candida albicans</i>		+		193, 195, 196

Supplementary Table 1. List of candidate mucinases from the various genomes described in Table 2. Candidate mucinases were selected from the signalP-based predicted secretomes, based on search parameters from Table 1.

Akkermansia muciniphila ATCC BAA-835

Gene Identifier Predicted function

Amuc_1187	Alpha-galactosidase
Amuc_0010	Alpha-L-fucosidase
Amuc_0146	Alpha-L-fucosidase
Amuc_0060	Alpha-N-acetylglucosaminidase
Amuc_1220	Alpha-N-acetylglucosaminidase
Amuc_0771	Beta-galactosidase
Amuc_1686	Beta-galactosidase
Amuc_0697	beta-glucanase precursor
Amuc_0698	beta-glucanase precursor
Amuc_0369	Beta-N-acetylhexosaminidase
Amuc_0397	Beta-N-acetylhexosaminidase
Amuc_0868	Beta-N-acetylhexosaminidase
Amuc_1032	Beta-N-acetylhexosaminidase
Amuc_1669	Beta-N-acetylhexosaminidase
Amuc_1815	Beta-N-acetylhexosaminidase
Amuc_1924	Beta-N-acetylhexosaminidase
Amuc_2018	Beta-N-acetylhexosaminidase
Amuc_2019	Beta-N-acetylhexosaminidase
Amuc_2148	Beta-N-acetylhexosaminidase
Amuc_1631	carboxyl-terminal protease
Amuc_0625	Exo-alpha-sialidase
Amuc_1835	Exo-alpha-sialidase
Amuc_0875	glycoside hydrolase family 16
Amuc_2108	glycoside hydrolase family 16
Amuc_2164	glycoside hydrolase family 18
Amuc_0290	glycoside hydrolase family 2 sugar binding
Amuc_0539	glycoside hydrolase family 2 sugar binding
Amuc_1667	glycoside hydrolase family 2 sugar binding
Amuc_0824	glycoside hydrolase family 2 TIM barrel
Amuc_1666	glycoside hydrolase family 2 TIM barrel
Amuc_1008	glycoside hydrolase family 31
Amuc_0186	glycoside hydrolase family 95
Amuc_2136	Glycoside hydrolase, family 20, catalytic core
Amuc_0623	glycosyl hydrolase BNR repeat-containing protein
Amuc_0863	glycosyl hydrolase family 88
Amuc_1438	Glycosyl hydrolase family 98 putative carbohydrate binding module
Amuc_0482	hydrolase of the alpha/beta superfamily
Amuc_1003	hydrolase of the alpha/beta superfamily
Amuc_1934	imelysin. Metallo peptidase. MEROPS family M75 (IMGterm)
Amuc_0253	Peptidase M23
Amuc_0391	Peptidase M23
Amuc_0465	Peptidase M23
Amuc_1106	peptidase M24

Amuc\_0187 peptidase M28  
 Amuc\_0176 peptidase S1 and S6 chymotrypsin/Hap  
 Amuc\_1791 peptidase S1 and S6 chymotrypsin/Hap  
 Amuc\_1480 peptidase S11 D-alanyl-D-alanine carboxypeptidase 1  
 Amuc\_1801 peptidase S15  
 Amuc\_2040 peptidyl-dipeptidase Dcp (EC 3.4.15.5). Metallo peptidase.  
 MEROPS family M03A (IMGterm)  
 Amuc\_0121 sulfatase  
 Amuc\_0451 sulfatase  
 Amuc\_0491 sulfatase  
 Amuc\_0565 sulfatase  
 Amuc\_0953 sulfatase  
 Amuc\_1033 sulfatase  
 Amuc\_1074 sulfatase  
 Amuc\_1118 sulfatase  
 Amuc\_1182 sulfatase  
 Amuc\_1655 sulfatase  
 Amuc\_1755 sulfatase  
 Amuc\_0670 Trypsin-like protein serine protease typically periplasmic  
 contain C-terminal PDZ domain-like protein

Bacteroides thetaiotaomicron VPI-5482

Gene Identifier Predicted function

BT0065 alpha-galactosidase precursor  
 BT0132 alpha-glucosidase, putative (EC:3.2.1.20)  
 BT0144 putative beta-xylosidase  
 BT0146 unsaturated glucuronyl hydrolase  
 BT0149 peptidase (EC:3.4.24.-)  
 BT0152 acetyl esterase (acetylxylosidase)  
 BT0212 protease  
 BT0290 beta-galactosidase precursor (EC:3.2.1.23)  
 BT0348 alpha-L-arabinofuranosidase (EC:3.2.1.55)  
 BT0360 putative arabinan endo-1,5-alpha-L-arabinosidase  
 (EC:3.2.1.99)  
 BT0367 putative endo-arabinase (EC:3.2.1.99)  
 BT0368 alpha-L-arabinofuranosidase A precursor (EC:3.2.1.55)  
 BT0369 endo-1,4-beta-xylanase D precursor  
 BT0445 endoglucanase E precursor (EGE)  
 BT0455 sialidase (Neuraminidase) (EC:3.2.1.18)  
 BT0456 beta-hexosaminidase precursor  
 BT0457 sialic acid-specific 9-O-acetylcysteine esterase (EC:3.1.1.53)  
 BT0458 beta-mannosidase (EC 3.2.1.25) (IMGterm)  
 BT0459 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT0460 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT0461 beta-galactosidase  
 BT0506 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT0587 prolyl oligopeptidase family protein  
 BT0683 alpha-glucosidase (EC:3.2.1.20)  
 BT0757 beta-galactosidase  
 BT0983 beta-galactosidase  
 BT0985 putative sialic acid-specific acetyl esterase II (EC:3.1.1.53)

BT0992 beta-galactosidase  
BT0993 beta-galactosidase (EC:3.2.1.23)  
BT0996 beta-galactosidase  
BT1001 putative alpha-rhamnosidase  
BT1013 putative alpha-rhamnosidase  
BT1018 polygalacturonase (Pectinase)  
BT1048 putative secreted endoglycosidase  
BT1051 beta-hexosaminidase precursor (EC:3.2.1.52)  
BT1087 putative xylanase  
BT1161 putative aminopeptidase C (EC:3.4.22.40)  
BT1192 putative xylanase  
BT1284 putative endo-beta-N-acetylglucosaminidase F1 precursor  
(mannosyl-glycoprotein endo-beta-N-acetyl-glucosaminidase F1)  
BT1285 endo-beta-N-acetylglucosaminidase  
BT1312 serine protease precursor  
BT1314 dipeptidyl-peptidase VI  
BT1549 putative secreted peptidase  
BT1596 putative sulfatase yidJ  
BT1621 beta-hexosaminidase precursor  
BT1622 N-acetylgalactosamine-6-sulfatase precursor  
BT1624 putative secreted sulfatase  
BT1626 beta-galactosidase (EC:3.2.1.23)  
BT1627 beta-hexosaminidase precursor (EC:3.2.1.52)  
BT1663 pullulanase (EC 3.2.1.41) (IMGterm)  
BT1759 levanase precursor (2,6-beta-D-fructofuranosidase)  
(EC:3.2.1.65)  
BT1760 glycosylhydrolase  
BT1765 levanase precursor (2,6-beta-D-fructofuranosidase)  
(EC:3.2.1.65)  
BT1768 beta-galactosidase  
BT1776 beta-galactosidase  
BT1778 exo-1,4-beta-glucosidase (EC 3.2.1.74) (IMGterm)  
BT1779 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
BT1780 periplasmic beta-glucosidase precursor (EC:3.2.1.21)  
BT1789 aminopeptidase C (bleomycin hydrolase)  
BT1842 alpha-L-fucosidase precursor (EC:3.2.1.51)  
BT1871 putative alpha-glucosidase  
BT1872 periplasmic beta-glucosidase precursor (EC:3.2.1.21)  
BT1873 endo-arabinase  
BT1879 signal peptide peptidase A. Serine peptidase. MEROPS family  
S49 (IMGterm)  
BT1883 putative alpha-1,6-mannanase  
BT2003 putative membrane peptidase  
BT2086 penicillin amidase (EC 3.5.1.11). Cysteine peptidase. MEROPS  
family C59 (IMGterm)  
BT2105 putative alpha-1,2-mannosidase  
BT2189 aminopeptidase  
BT2191 beta-galactosidase  
BT2199 alpha-1,2-mannosidase  
BT2239 carboxyl-terminal protease  
BT2378 endo-polygalacturonase  
BT2432 beta-mannosidase precursor  
BT2436 putative secreted tripeptidyl aminopeptidase  
BT2439 beta-N-acetylglucosaminidase

BT2479 imelysin. Metallo peptidase. MEROPS family M75 (IMGterm)  
BT2523 alpha-rhamnosidase  
BT2524 alpha-rhamnosidase  
BT2548 leucine aminopeptidase precursor  
BT2550 beta-glucanase precursor  
BT2620 alpha-glucosidase  
BT2622 alpha-glucuronidase (EC:3.2.1.139)  
BT2623 putative alpha-1,6-mannanase  
BT2629 putative alpha-1,2-mannosidase  
BT2631 putative hydrolase  
BT2680 beta-galactosidase (EC:3.2.1.23)  
BT2798 C-terminal processing peptidase-3. Serine peptidase. MEROPS  
family S41A (IMGterm)  
BT2824 beta-glucanase precursor  
BT2834 peptidyl-dipeptidase Dcp (EC 3.4.15.5). Metallo peptidase.  
MEROPS family M03A (IMGterm)  
BT2851 alpha-galactosidase (melibiase) (EC:3.2.1.22)  
BT2852 putative beta-xylosidase  
BT2854 periplasmic beta-glucosidase precursor  
BT2855 beta-mannosidase precursor  
BT2895 endo-1,4-beta-xylanase  
BT2898 endo-1,4-beta-xylanase D precursor  
BT2900 arabinan endo-1,5-alpha-L-arabinosidase A precursor  
(EC:3.2.1.99)  
BT2912 putative glycosylhydrolase  
BT2913 unsaturated glucuronylhydrolase  
BT2922 beta-galactosidase  
BT2949 putative alpha-1,6-mannanase  
BT2969 beta-galactosidase (EC:3.2.1.23)  
BT2970 alpha-L-fucosidase precursor (EC:3.2.1.51)  
BT3009 beta-glucosidase (gentiobiase) (EC:3.2.1.21)  
BT3026 glycosylhydrolase, putative xylanase  
BT3035 C-terminal processing peptidase-3. Serine peptidase. MEROPS  
family S41A (IMGterm)  
BT3043 putative xylanase  
BT3051 mucin-desulfating sulfatase (EC:3.1.6.14)  
BT3057 N-acetylgalactosamine-6-sulfatase precursor  
BT3065 alpha-galactosidase precursor (EC:3.2.1.22)  
BT3082 2,6-beta-D-fructofuranosidase precursor (EC:3.2.1.65)  
BT3085 alpha-xylosidase  
BT3086 alpha-glucosidase II (EC:3.2.1.20)  
BT3092 beta-galactosidase  
BT3094 putative secreted xylosidase  
BT3095 putative sulfatase  
BT3108 putative beta-xylosidase  
BT3114 beta-galactosidase  
BT3124 putative sialic acid-specific acetylcysteine (EC:3.1.1.53)  
BT3131 alpha-galactosidase (melibiase) (EC:3.2.1.22)  
BT3132 sialic acid-specific 9-O-acetylcysteine (EC:3.1.1.53)  
BT3133 alpha-galactosidase  
BT3163 alpha-glucosidase, putative (EC:3.2.1.20)  
BT3169 alpha-xylosidase  
BT3171 sialic acid-specific 9-O-acetylcysteine (EC:3.1.1.53)  
BT3177 mucin-desulfating sulfatase

BT3178 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT3179 beta-galactosidase (EC:3.2.1.23)  
 BT3254 prolyl tripeptidyl peptidase. Serine peptidase. MEROPS family  
 S09B (IMGterm)  
 BT3292 beta-glucuronidase  
 BT3293 beta-galactosidase (EC:3.2.1.23)  
 BT3294 putative alpha-glucosidase  
 BT3300 beta-glucosidase (EC:3.2.1.21, EC:3.2.1.21)  
 BT3301 putative alpha-1,6-mannanase  
 BT3314 thermostable beta-glucosidase B (EC:3.2.1.21)  
 BT3318 signal peptidase I (EC:3.4.21.89)  
 BT3340 beta-galactosidase (EC:3.2.1.23)  
 BT3464 putative peptidase  
 BT3467 putative glycosylhydrolase  
 BT3486 N-acetylgalactosamine-6-sulfatase precursor (EC:3.1.6.4)  
 BT3513 beta-galactosidase  
 BT3516 arabinan endo-1,5-alpha-L-arabinosidase A precursor  
 BT3521 alpha-1,6-mannanase  
 BT3524 alpha-1,6-mannanase  
 BT3526 L-glutaminase (EC 3.5.1.2) (IMGterm)  
 BT3527 alpha-1,2-mannosidase  
 BT3546 L-glutaminase (EC 3.5.1.2) (IMGterm)  
 BT3567 periplasmic beta-glucosidase precursor (EC:3.2.1.21)  
 BT3590 alpha-N-acetylglucosaminidase precursor (EC:3.2.1.50)  
 BT3592 alpha-galactosidase precursor (EC:3.2.1.22)  
 BT3597 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
 BT3598 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT3599 beta-mannosidase precursor  
 BT3648 microcin-processing peptidase 2. Unknown type peptidase.  
 MEROPS family U62 (IMGterm)  
 BT3654 beta-galactosidase precursor (EC:3.2.1.23)  
 BT3655 arabinosidase  
 BT3656 putative beta-xylosidase  
 BT3657 alpha-L-arabinofuranosidase A precursor  
 BT3659 alpha-xylosidase  
 BT3661 alpha-glucosidase  
 BT3662 putative endo-1,4-beta-xylanase  
 BT3665 alpha-L-fucosidase precursor (EC:3.2.1.51)  
 BT3675 endo-1,4-beta-xylanase D precursor  
 BT3683 beta-glucanase precursor  
 BT3698 neopullulanase (EC 3.2.1.135) (IMGterm)  
 BT3703 alpha-glucosidase (EC:3.2.1.20) (IMGterm)  
 BT3704 neopullulanase (EC 3.2.1.135) (IMGterm)  
 BT3774 alpha-mannosidase (EC:3.2.1.24)  
 BT3782 putative hydrolase  
 BT3784 putative alpha-1,2-mannosidase  
 BT3792 putative alpha-1,6-mannanase  
 BT3796 putative secreted sulfatase ydeN precursor  
 BT3799 putative sulfatase yidJ  
 BT3862 endo-alpha-mannosidase  
 BT3868 beta-N-hexosaminidase, glycosyl hydrolase family 20  
 (EC:3.2.1.52)  
 BT3889 subtilisin-like serine protease  
 BT3905 putative alkaline protease aprF

BT3926 putative peptidase  
 BT3962 putative sugar hydrolase  
 BT3963 putative sugar hydrolase  
 BT3987 endo-beta-N-acetylglucosaminidase F1 precursor  
 BT3990 putative alpha-1,2-mannosidase  
 BT3991 putative alpha-1,2-mannosidase  
 BT3994 putative alpha-1,2-mannosidase  
 BT4007 AAA-metalloprotease FtsH, with ATPase domain (EC:3.4.24.-)  
 BT4050 beta-galactosidase (EC:3.2.1.23)  
 BT4072 alpha-mannosidase  
 BT4074 beta-mannosidase precursor  
 BT4076 alpha-rhamnosidase  
 BT4077 endo-1,4-beta-xylanase Z precursor  
 BT4091 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
 BT4092 putative alpha-1,2-mannosidase  
 BT4095 beta-xylosidase (1,4-beta-D-xylan xylosidase)  
 BT4109 putative pectinesterase precursor  
 BT4123 exo-poly-alpha-D-galacturonosidase precursor  
 BT4146 exo-poly-alpha-D-galacturonosidase precursor  
 BT4149 exo-poly-alpha-D-galacturonosidase precursor  
 BT4150 putative rhamnogalacturonan acetylerase  
 BT4151 beta-glucuronidase  
 BT4152 beta-galactosidase I (EC:3.2.1.23)  
 BT4153 Exopolygalacturonase precursor  
 BT4156 beta-galactosidase  
 BT4160 beta-galactosidase precursor  
 BT4180 acetyl xylan esterase A  
 BT4181 beta-galactosidase (EC:3.2.1.23)  
 BT4185 xylosidase/arabinosidase  
 BT4193 dipeptidyl-peptidase IV (EC:3.4.14.5). Serine peptidase.  
 MEROPS family S09B (IMGterm)  
 BT4320 putative zinc protease (EC:3.4.99.-)  
 BT4359 alpha-N-acetylglucosaminidase precursor  
 BT4391 putative metalloendopeptidase  
 BT4394 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT4395 N-acetyl beta-glucosaminidase (EC:3.2.1.52) (IMGterm)  
 BT4507 beta-lactamase precursor (EC:3.5.2.6)  
 BT4581 alpha-glucosidase (EC:3.2.1.20)  
 BT4632 putative galactose oxidase precursor  
 BT4656 N-acetylglucosamine-6-sulfatase precursor  
 BT4658 glucuronyl hydrolase  
 BT4667 beta-galactosidase  
 BT4668 arabinogalactan endo-1,4-beta-galactosidase (EC:3.2.1.89)  
 BT4681 beta-hexosaminidase precursor (EC:3.2.1.52)  
 BT4684 beta-galactosidase

Bacteroides vulgatus ATCC 8482

Gene Identifier Predicted function

BVU\_0746 alpha-galactosidase  
 BVU\_1865 aminopeptidase  
 BVU\_3875 aminopeptidase C



BVU\_2072 aminopeptidase C  
BVU\_1274 aminopeptidase N (EC:3.4.11.2)  
BVU\_2792 asparaginase (EC 3.5.1.1) (IMGterm)  
BVU\_0301 beta-galactosidase (EC:3.2.1.23) (IMGterm)  
BVU\_4139 beta-mannosidase (EC 3.2.1.25) (IMGterm)  
BVU\_1237 C-terminal processing peptidase-3. Serine peptidase. MEROPS family S41A (IMGterm)  
BVU\_0835 C-terminal processing peptidase-3. Serine peptidase. MEROPS family S41A (IMGterm)  
BVU\_2624 C-terminal processing peptidase-3. Serine peptidase. MEROPS family S41A (IMGterm)  
BVU\_0182 carbohydrate esterase family 12  
BVU\_2160 carbohydrate esterase family 12  
BVU\_0160 carbohydrate esterase family 12 protein  
BVU\_1798 carbohydrate esterase family 8  
BVU\_1803 carbohydrate esterase family 8  
BVU\_1815 carbohydrate esterase family 8  
BVU\_2023 conserved hypothetical protein, putative pectinesterase precursor  
BVU\_3876 dipeptidyl aminopeptidase (EC:3.4.14.5)  
BVU\_1818 dipeptidyl peptidase IV  
BVU\_1292 dipeptidyl-peptidase 7. Serine peptidase. MEROPS family S46 (IMGterm)  
BVU\_2253 dipeptidyl-peptidase 7. Serine peptidase. MEROPS family S46 (IMGterm)  
BVU\_2252 dipeptidyl-peptidase 7. Serine peptidase. MEROPS family S46 (IMGterm)  
BVU\_1991 dipeptidyl-peptidase IV (EC:3.4.14.5). Serine peptidase. MEROPS family S09B (IMGterm)  
BVU\_2033 endothelin-converting enzyme (EC 3.4.24.71). Metallo peptidase. MEROPS family M13 (IMGterm)  
BVU\_0615 exo-alpha sialidase  
BVU\_1106 gluconate 5-dehydrogenase (EC:1.1.1.69)  
BVU\_0041 glycoside hydrolase family 10, candidate beta-xylanase (EC:3.2.1.8)  
BVU\_1382 glycoside hydrolase family 13, candidate alpha-glycosidase  
BVU\_0044 glycoside hydrolase family 16, candidate beta-glycosidase  
BVU\_1273 glycoside hydrolase family 18  
BVU\_0617 glycoside hydrolase family 18  
BVU\_2910 glycoside hydrolase family 2  
BVU\_1365 glycoside hydrolase family 2 (EC:3.2.1.23)  
BVU\_4134 glycoside hydrolase family 2, candidate beta-galactosidase  
BVU\_0607 glycoside hydrolase family 2, candidate beta-galactosidase (EC:3.2.1.23)  
BVU\_2694 glycoside hydrolase family 2, candidate beta-galactosidase (EC:3.2.1.23)  
BVU\_0997 glycoside hydrolase family 2, candidate beta-galactosidase (EC:3.2.1.23)  
BVU\_1808 glycoside hydrolase family 2, candidate beta-glycosidase  
BVU\_1809 glycoside hydrolase family 2, candidate beta-glycosidase  
BVU\_2688 glycoside hydrolase family 2, candidate beta-glycosidase  
BVU\_2224 glycoside hydrolase family 2, candidate beta-glycosidase  
BVU\_3844 glycoside hydrolase family 2, candidate beta-glycosidase  
BVU\_2162 glycoside hydrolase family 2, candidate beta-glycosidase

BVU\_2171 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_1151 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_1785 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_2695 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_0181 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_1768 glycoside hydrolase family 2, candidate beta-glycosidase  
 BVU\_0162 glycoside hydrolase family 2, candidate beta-glycosidase  
 (EC:3.2.1.23)  
 BVU\_0536 glycoside hydrolase family 2, candidate beta-glycosidase  
 (EC:3.2.1.23)  
 BVU\_0391 glycoside hydrolase family 2, candidate beta-glycosidase  
 (EC:3.2.1.23)  
 BVU\_0742 glycoside hydrolase family 2, candidate beta-glycosidase;  
 contains a CBM35 module  
 BVU\_4142 glycoside hydrolase family 20  
 BVU\_1196 glycoside hydrolase family 20 (EC:3.2.1.52)  
 BVU\_0085 glycoside hydrolase family 20, candidate beta-N-  
 acetylhexosaminidase (EC:3.2.1.52)  
 BVU\_0537 glycoside hydrolase family 20, candidate beta-N-  
 acetylhexosaminidase (EC:3.2.1.52)  
 BVU\_3245 glycoside hydrolase family 20, candidate beta-N-  
 acetylhexosaminidase (EC:3.2.1.52)  
 BVU\_4138 glycoside hydrolase family 20, candidate beta-N-  
 acetylhexosaminidase (EC:3.2.1.52)  
 BVU\_2209 glycoside hydrolase family 20, candidate beta-N-  
 acetylhexosaminidase (EC:3.2.1.52)  
 BVU\_0605 glycoside hydrolase family 23  
 BVU\_2357 glycoside hydrolase family 23  
 BVU\_1912 glycoside hydrolase family 23 (EC:3.2.1.-)  
 BVU\_0659 glycoside hydrolase family 24  
 BVU\_1573 glycoside hydrolase family 24  
 BVU\_0640 glycoside hydrolase family 27  
 BVU\_0177 glycoside hydrolase family 28  
 BVU\_1767 glycoside hydrolase family 28  
 BVU\_0121 glycoside hydrolase family 28  
 BVU\_2163 glycoside hydrolase family 28  
 BVU\_0186 glycoside hydrolase family 28  
 BVU\_0124 glycoside hydrolase family 28  
 BVU\_0183 glycoside hydrolase family 28  
 BVU\_1985 glycoside hydrolase family 28  
 BVU\_1769 glycoside hydrolase family 28  
 BVU\_2168 glycoside hydrolase family 28  
 BVU\_0153 glycoside hydrolase family 28, candidate polygalacturonase  
 BVU\_1747 glycoside hydrolase family 28, candidate polygalacturonase  
 BVU\_2732 glycoside hydrolase family 28, candidate polygalacturonase  
 (EC:3.2.1.67)  
 BVU\_1745 glycoside hydrolase family 29 (EC:3.2.1.51)  
 BVU\_4052 glycoside hydrolase family 29 (EC:3.2.1.51)  
 BVU\_1046 glycoside hydrolase family 29 (EC:3.2.1.51)  
 BVU\_0217 glycoside hydrolase family 29 (EC:3.2.1.51)  
 BVU\_1246 glycoside hydrolase family 29 (EC:3.2.1.51)  
 BVU\_0102 glycoside hydrolase family 29, candidate alpha-L-fucosidase  
 BVU\_2433 glycoside hydrolase family 29, candidate alpha-L-fucosidase  
 (EC:3.2.1.51)

BVU\_0535 glycoside hydrolase family 29, candidate alpha-L-fucosidase  
(EC:3.2.1.51)  
BVU\_0741 glycoside hydrolase family 3, candidate beta-glycosidase  
BVU\_0145 glycoside hydrolase family 3, candidate beta-glycosidase  
BVU\_0556 glycoside hydrolase family 3, candidate beta-glycosidase  
(EC:3.2.1.21)  
BVU\_0131 glycoside hydrolase family 3, candidate beta-glycosidase  
(EC:3.2.1.21)  
BVU\_1162 glycoside hydrolase family 3, candidate beta-glycosidase  
(EC:3.2.1.21)  
BVU\_0498 glycoside hydrolase family 30, candidate beta-glycosidase  
(EC:3.2.1.45)  
BVU\_2170 glycoside hydrolase family 30, candidate beta-glycosidase  
(EC:3.2.1.45)  
BVU\_0212 glycoside hydrolase family 31, candidate alpha-glycosidase  
BVU\_0491 glycoside hydrolase family 31, candidate alpha-glycosidase  
BVU\_1810 glycoside hydrolase family 31, candidate alpha-glycosidase  
(EC:3.2.1.20)  
BVU\_1801 glycoside hydrolase family 33  
BVU\_4143 glycoside hydrolase family 33, candidate sialidase  
(EC:3.2.1.18)  
BVU\_0495 glycoside hydrolase family 35, candidate beta-glycosidase  
(EC:3.2.1.23)  
BVU\_1047 glycoside hydrolase family 36, candidate alpha-glycosidase  
BVU\_0736 glycoside hydrolase family 36, candidate alpha-glycosidase  
(EC:3.2.1.22)  
BVU\_0179 glycoside hydrolase family 42 (EC:3.2.1.23)  
BVU\_2230 glycoside hydrolase family 43  
BVU\_0507 glycoside hydrolase family 43  
BVU\_1790 glycoside hydrolase family 43  
BVU\_0031 glycoside hydrolase family 43  
BVU\_0497 glycoside hydrolase family 43  
BVU\_0180 glycoside hydrolase family 43  
BVU\_1123 glycoside hydrolase family 43  
BVU\_0509 glycoside hydrolase family 43  
BVU\_0032 glycoside hydrolase family 43  
BVU\_2229 glycoside hydrolase family 43  
BVU\_2231 glycoside hydrolase family 43 (EC:3.2.1.99)  
BVU\_1002 glycoside hydrolase family 43 (EC:3.2.1.99)  
BVU\_1008 glycoside hydrolase family 43 (EC:3.2.1.99)  
BVU\_0508 glycoside hydrolase family 43, candidate beta-glycosidase  
BVU\_0116 glycoside hydrolase family 43, candidate beta-  
xylosidase/alpha-L-arabinofuranosidase  
BVU\_1983 glycoside hydrolase family 43, candidate beta-  
xylosidase/alpha-L-arabinofuranosidase  
BVU\_0039 glycoside hydrolase family 43, candidate beta-  
xylosidase/alpha-L-arabinofuranosidase (EC:3.2.1.55)  
BVU\_0844 glycoside hydrolase family 5, candidate beta-glycosidase  
BVU\_0843 glycoside hydrolase family 5, candidate beta-glycosidase  
BVU\_0496 glycoside hydrolase family 51  
BVU\_4054 glycoside hydrolase family 51, candidate alpha-L-  
arabinofuranosidase (EC:3.2.1.55)  
BVU\_1001 glycoside hydrolase family 51, candidate alpha-L-  
arabinofuranosidase (EC:3.2.1.55)

BVU\_1364 glycoside hydrolase family 63  
 BVU\_0302 glycoside hydrolase family 63  
 BVU\_0029 glycoside hydrolase family 67, candidate alpha-glucuronidase  
 (EC:3.2.1.139)  
 BVU\_2342 glycoside hydrolase family 73  
 BVU\_2645 glycoside hydrolase family 78  
 BVU\_0174 glycoside hydrolase family 78  
 BVU\_2648 glycoside hydrolase family 78  
 BVU\_2731 glycoside hydrolase family 78  
 BVU\_2069 glycoside hydrolase family 84 (EC:3.2.1.35)  
 BVU\_0115 glycoside hydrolase family 88, candidate delta-4,5  
 unsaturated glucuronyl hydrolase  
 BVU\_0137 glycoside hydrolase family 88, candidate delta-4,5  
 unsaturated glucuronyl hydrolase  
 BVU\_1749 glycoside hydrolase family 88, candidate delta-4,5  
 unsaturated glucuronyl hydrolase  
 BVU\_1860 glycoside hydrolase family 89 (EC:3.2.1.50)  
 BVU\_0555 glycoside hydrolase family 92  
 BVU\_0755 glycoside hydrolase family 92  
 BVU\_0628 glycoside hydrolase family 92  
 BVU\_4135 glycoside hydrolase family 92  
 BVU\_0625 glycoside hydrolase family 92  
 BVU\_0754 glycoside hydrolase family 92  
 BVU\_0624 glycoside hydrolase family 92  
 BVU\_0752 glycoside hydrolase family 92  
 BVU\_0753 glycoside hydrolase family 95  
 BVU\_2642 glycoside hydrolase family 95  
 BVU\_1268 glycoside hydrolase family 95  
 BVU\_2979 glycoside hydrolase family 95  
 BVU\_0213 glycoside hydrolase family 97  
 BVU\_1004 glycoside hydrolase family 97  
 BVU\_1124 glycoside hydrolase family 97  
 BVU\_0133 glycoside hydrolase family 97 (EC:3.2.1.20)  
 BVU\_0117 glycoside hydrolase family 97 (EC:3.2.1.20)  
 BVU\_1381 glycoside hydrolase family 97, candidate alpha-glucosidase  
 (EC:3.2.1.20)  
 BVU\_2058 hydrolase of the alpha/beta superfamily  
 BVU\_1947 IgA peptidase. Metallo peptidase. MEROPS family M64 (IMGterm)  
 BVU\_1317 leucine aminopeptidase precursor  
 BVU\_3993 penicillin amidase (EC 3.5.1.11). Cysteine peptidase. MEROPS  
 family C59 (IMGterm)  
 BVU\_1121 peptidase  
 BVU\_3057 peptidase (EC:3.4.24.-)  
 BVU\_0992 peptidyl-dipeptidase Dcp (EC 3.4.15.5). Metallo peptidase.  
 MEROPS family M03A (IMGterm)  
 BVU\_3439 peptidyl-dipeptidase Dcp (EC 3.4.15.5). Metallo peptidase.  
 MEROPS family M03A (IMGterm)  
 BVU\_3355 prolyl oligopeptidase family protein  
 BVU\_1094 prolyl tripeptidyl peptidase. Serine peptidase. MEROPS family  
 S09B (IMGterm)  
 BVU\_3018 putative acylaminoacyl-peptidase  
 BVU\_4083 putative alanyl dipeptidyl peptidase  
 BVU\_1624 putative aminopeptidase  
 BVU\_2992 putative aminopeptidase

BVU\_3228 putative aminopeptidase C (EC:3.4.22.40)  
 BVU\_4071 putative exported peptidase  
 BVU\_0587 putative glycoside hydrolase  
 BVU\_2161 putative glycoside hydrolase  
 BVU\_0189 putative L-asparaginase (EC:3.5.1.1)  
 BVU\_1686 putative metalloendopeptidase  
 BVU\_0469 putative peptidase  
 BVU\_1412 putative peptidase  
 BVU\_1192 putative peptidase/protease family protein (EC:3.4.21.-)  
 BVU\_3874 putative secreted peptidase  
 BVU\_3805 putative secreted peptidase  
 BVU\_1048 putative secreted sulfatase precursor  
 BVU\_1466 putative secreted tripeptidyl aminopeptidase  
 BVU\_1045 putative sulfatase  
 BVU\_0538 putative sulfatase  
 BVU\_2755 putative xylanase  
 BVU\_3345 putative xylanase  
 BVU\_0541 putative xylanase  
 BVU\_3629 putative zinc protease (EC:3.4.99.-)  
 BVU\_2737 serine protease precursor  
 BVU\_4141 sialate O-acetylerase  
 BVU\_4140 sialate O-acetylerase (EC:3.1.1.53)  
 BVU\_3835 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
 BVU\_0028 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
 BVU\_0738 sialic acid-specific 9-O-acetylerase (EC:3.1.1.53)  
 BVU\_0064 signal peptidase I  
 BVU\_1159 sulfatase

*Bifidobacterium longum infantis*

Gene Identifier Predicted function

Blon\_1942 Alpha/beta hydrolase fold-3 domain protein  
 Blon\_1647 family M20D unassigned peptidase  
 Blon\_1654 glycoside hydrolase, family 25  
 Blon\_1571 glycoside hydrolase, family 25  
 Blon\_1831 glycoside hydrolase, family 25  
 Blon\_1100 glycoside hydrolase, family 25  
 Blon\_1843 glycoside hydrolase, family 3 domain protein (EC:3.2.1.52)  
 Blon\_2468 glycosyl hydrolase, family 20  
 Blon\_0117 Heat shock protein. Metallo peptidase. MEROPS family M48B (IMGterm)  
 Blon\_1280 peptidase C60, sortase A and B  
 Blon\_1049 peptidase M23B  
 Blon\_0776 peptidase S16, lon domain protein  
 Blon\_0084 peptidase S9, prolyl oligopeptidase active site domain protein (EC:3.4.14.5)  
 Blon\_0804 signal peptidase II (EC:3.4.23.36). Aspartic peptidase. MEROPS family A08 (IMGterm)  
 Blon\_1962 sulfatase

*Helicobacter pylori* J99

Gene Identifier Predicted function

jhp1269 CARBOXYL-TERMINAL PROTEASE (EC:3.4.21.102)  
jhp0405 PROTEASE DO (EC:3.4.21.107)  
jhp0602 putative PROCESSING PROTEASE  
jhp0411 putative ZINC PROTEASE  
jhp0523 SIGNAL PEPTIDASE I (EC:3.4.21.89)  
jhp0069 signal peptidase II (EC:3.4.23.36). Aspartic peptidase.  
MEROPS family A08 (IMGterm)

*Porphyromonas gingivalis* ATCC 33277

Gene Identifier Predicted function

PGN\_0405 alpha-1,2-mannosidase family protein  
PGN\_1970 arginine-specific cysteine proteinase RgpA  
PGN\_1466 arginine-specific cysteine proteinase RgpB (EC:3.4.22.37)  
PGN\_1045 beta-galactosidase  
PGN\_0701 beta-galactosidase (EC:3.2.1.23)  
PGN\_0039 beta-hexosaminidase (EC:3.2.1.52, EC:3.2.1.52)  
PGN\_0295 C-terminal domain of Arg- and Lys-gingipain proteinase  
PGN\_0340 C-terminal processing peptidase-3. Serine peptidase. MEROPS  
family S41A (IMGterm)  
PGN\_1788 C-terminal processing peptidase-3. Serine peptidase. MEROPS  
family S41A (IMGterm)  
PGN\_1914 C-terminal processing peptidase-3. Serine peptidase. MEROPS  
family S41A (IMGterm)  
PGN\_0952 carboxyl-terminal processing protease (EC:3.4.21.102)  
PGN\_0406 conserved hypothetical protein with glycosyl hydrolase family  
92 domain  
PGN\_0335 conserved hypothetical protein with Zinc carboxypeptidase  
domain  
PGN\_1103 dipeptidase  
PGN\_1479 dipeptidyl-peptidase 7. Serine peptidase. MEROPS family S46  
(IMGterm)  
PGN\_0607 dipeptidyl-peptidase 7. Serine peptidase. MEROPS family S46  
(IMGterm)  
PGN\_1469 dipeptidyl-peptidase IV (EC:3.4.14.5). Serine peptidase.  
MEROPS family S09B (IMGterm)  
PGN\_0009 glycosyl hydrolase family 3  
PGN\_0788 peptidyl-dipeptidase Dcp (EC 3.4.15.5). Metallo peptidase.  
MEROPS family M03A (IMGterm)  
PGN\_1349 probable dipeptidyl aminopeptidase  
PGN\_0202 probable leucine aminopeptidase precursor  
PGN\_1416 probable lysyl endopeptidase precursor  
PGN\_0099 probable peptidase  
PGN\_1608 probable sialidase (EC:3.2.1.18)  
PGN\_0756 prolyl oligopeptidase  
PGN\_1149 prolyl tripeptidyl peptidase. Serine peptidase. MEROPS family  
S09B (IMGterm)  
PGN\_1694 putative alanyl dipeptidyl peptidase  
PGN\_2041 putative alkaline protease AprF  
PGN\_0980 putative alpha-1,2-mannosidase family protein  
PGN\_2032 putative alpha-galactosidase (EC:3.2.1.22)

PGN\_1811 putative alpha-L-fucosidase  
 PGN\_0508 putative aminopeptidase (EC:3.4.22.40)  
 PGN\_0637 putative heat shock-related protease htrA protein  
 PGN\_0993 putative peptidase M23/M37 family  
 PGN\_2064 putative peptidase M48 family  
 PGN\_0303 putative zinc protease (EC:3.4.99.-)  
 PGN\_0680 signal peptide peptidase SppA 67K type (EC:3.4.21.-)  
 PGN\_0561 trypsin like proteinase PrtT

Streptococcus mutans UA159

Gene Identifier Predicted function

SMU.1881c bacteriocin-processing peptidase. Cysteine peptidase. MEROPS family C39 (IMGterm)  
 SMU.15 membrane protease FtsH catalytic subunit (EC 3.4.24.-) (IMGterm)  
 SMU.79 fructan hydrolase; exo-beta-D-fructosidase; FruB  
 SMU.78 fructan hydrolase; exo-beta-D-fructosidase; fructanase, FruA (EC:3.2.1.80)  
 SMU.1929 Heat shock protein. Metallo peptidase. MEROPS family M48B (IMGterm)  
 SMU.467 penicillin-binding protein 1a; membrane carboxypeptidase (EC:2.4.1.-, EC:3.4.-)  
 SMU.1239 peptidase V. Metallo peptidase. MEROPS family M20A (IMGterm)  
 SMU.76 putative N-acetyl-muramidase (EC:3.5.1.28)  
 SMU.22 putative secreted antigen GbpB/SagA; putative peptidoglycan hydrolase  
 SMU.1188 putative signal peptidase (EC:3.4.21.89)  
 SMU.2164 serine protease HtrA  
 SMU.539c signal peptidase type IV (EC:3.4.23.43, EC:2.1.1.-)  
 SMU.1874 signal peptidase. Serine peptidase. MEROPS family S26A (IMGterm)  
 SMU.1438c putative Zn-dependent protease