Restriction and modification enzymes and their recognition sequences

Richard J. Roberts

Cold Spring Harbor Laboratory, Cold Spring Harbor, NY 11724, USA

Introduction

Since the last compilation of restriction endonucleases (194), 80 new entries have been added, including 12 new specificities. These are *Cfr*101 (PuCCGGPy), *Eco*47III (AGCGCT), *Eco*A (GAG(N)₇GTCA), *Mae*I (CTAG), *Mae*II (ACGT), *Mae*III (GTNAC), *Nla*III (CATG), *Nla*IV (GGNNCC), *Not*I (GCGGCCGC), *Sna*BI (TACGTA), *Sca*I (AGTACT) and *Sfi*I (GGCCNNNNNGGCC). *Not*I and *Sfi*I are the first examples of Type II enzymes that recognize octanucleotide sequences. In addition to these two new sequence patterns, one additional new sequence pattern is recognized by *Nla*IV. The first example of unusual methylation is provided in the *Bcn*I system where the methylase protects by the formation of N⁴-methylcytosine (109).

Among the 475 enzymes listed, there are a minimum of 103 different specificities. New entries, together with new information about recognition sequences, are indicated (®).

In forming this list, all endonucleases cleaving DNA at a specific sequence have been considered to be restriction enzymes, although in most cases there is no direct genetic evidence for the presence of a restriction-modification system. These endonucleases are named in accordance with the proposal of Smith and Nathans (234). Within the table, the source of each microorganism is given either as an individual or a National Culture Collection. If further information is required, it can be found either in the first reference which, in each case, refers to the purification procedure for the restriction enzyme, or from the individuals who have provided their unpublished results. Where more than one reference appears, the second concerns the recognition sequence for the restriction enzyme, the third describes the purification procedure for the methylase and the fourth describes the recognition sequence of the methylase. In some cases, several references appear in one of these categories when independent groups have reached similar conclusions.

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c			References
				Ad2	SV40	PBR	
Acetobacter aceti	IFO 3281	AatI (SkuI)	AGGCT	6	11	7	1 0 244
		AatII	GAGCTC	10	3	0	1 1 244
Acetobacter aceti sub. liquefaciens	IFO 12388	AacI (BamHI)	GGATCC	5	3	1	0 1 220
Acetobacter aceti sub. liquefaciens	M. Van Montagu	AaeI (BamHI)	GGATCC	5	3	1	0 1 220
Acetobacter aceti sub. orleanensis	NCIB 8622	AorI (BstNI)	CC(↓)G	71	136	17	2 6 220
Acetobacter pasteurianus sub. pasteurianus	NCIB 7215	ApaI	GGGCCTC	1	12	1	0 0 219
Achromobacter immobilis	ATCC 15934	AimI	?	?	?	?	?
Acinetobacter calcoaceticus	R.J. Roberts	AccI	CTT(↓)(↓)AC	9	17	1	2 2 286
		AccII (EcoRII)	CCG	157	303	0	14 23 286
		AccIII	?	>10	>6	?	?
Actinomyces madurae	ATCC 15904	AmaI (HruI)	TCCGA	5	5	0	2 1 103
Agmenellum quadruplicatum	W.F. Doolittle	AguI (AvaI)	CPYCPG	8	40	0	1 1 137
Agrobacterium tumefaciens	ATCC 15955	AtuAI	?	>30	>30	?	?
Agrobacterium tumefaciens B6806	E. Nester	AtuBI (EcoRII)	CC(↓)GG	71	136	17	2 6 201
Agrobacterium tumefaciens 11BV7	G. Roizes	AtuBI	?	>14	?	1	0 ?
Agrobacterium tumefaciens ID 135	C. Kado	AtuII (EcoRII)	CC(↓)GG	71	136	17	2 6 143
Agrobacterium tumefaciens C58	E. Nester	AtuCI (BclI)	TGATCA	8	5	1	0 0 218
Agrobacterium tumefaciens	IAM B-26-1	AtuAMI	?	?	?	?	?
Alcaligenes species	N. Brown	AadAI (BstEII)	GCTNACC	13	10	0	0 0 23

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
λ	Ad2	SV40	ΦX	PBR	
Anabaena catanula	CCAP 1403/1	AcaI	?	? ? ? ? ?	101
Anabaena cylindrica	CCAP 1403/2a	AcyI	GPuTCpYC	40 44 0 7 6	47
Anabaena flos-aquae	A.E. Walsby	AflI (AvaII)	GTG($\frac{A}{T}$)CC	35 73 6 1 8	277
		AflII	CTTTAAG	3 4 1 2 0	277
		AflIII	ATCPuPYGT	20 25 0 2 1	277
Anabaena oscillarioides	CCAP 1403/11	AosI (NsiI)	TCTCCA	15 17 0 1 4	48
		AosII (AcyI)	GPuTCpYC	40 44 0 7 6	48
Anabaena strain Waterbury	ATCC 29208	AsaWI (AcyI)	GPuTCpYC	40 44 0 7 6	46
Anabaena subcylindrica	CCAP 1403/4b	AsuI	GTGNCC	74 164 11 2 15	100
		AsuII	TTTCCA	7 1 0 0 0	175,46,46
Anabaena variabilis	ATCC 27892	AsuIII (AcyI)	GPuTCpYC	40 44 0 7 6	46
		AvaI	CTPyCpUG	8 40 0 1 1	172,102
		AvaII	GTG($\frac{A}{T}$)CC	35 73 6 1 8	172,250,102,61
		AvaIII	ATGCAT	14 9 3 0 0	199,199,226
Anabaena variabilis UW	E.C. Rosenfold	AvrI (AvaI)	CPyCpUG	8 40 0 1 1	203
e		AvrII	CTCTAGG	2 2 2 0 0	203,202
Aphanotheca halophytica	ATCC 29534	AhaI (CauII)	CC($\frac{G}{C}$)GG	114 97 0 1 10	277
e		AhaII (AcyI)	GPuTCpYC	40 44 0 7 6	277,23,213
		AhaIII	TTTTAAA	13 12 12 2 3	276
Arthrobacter luteus	ATCC 21606	AluI	AGCT	143 158 34 24 16	196
Arthrobacter pyridinolis	R. DiLauro	ApvI (BstNI)	CCf($\frac{A}{T}$)GG	71 136 17 2 6	49
Bacillus acidocaldarius	ATCC 27009	BacI (SacII)	CCGCGG	4 33 0 1 0	161,175

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c λ Ad2 SV40 ΦX PBR	References
Bacillus amyloliquefaciens F	ATCC 23350	BamFI (BamHI)	GGATCC	5 3 1 0 1	225
Bacillus amyloliquefaciens H	F. E. Young	BamHI	GTCATC	5 3 1 0 1	278,198,91,91
Bacillus amyloliquefaciens K	T. Kaneko	BamKI (BamHI)	GGATCC	5 3 1 0 1	225
Bacillus amyloliquefaciens N	T. Ando	BamNI (BamHI)	GGATCC	5 3 1 0 1	224
Bacillus aneurinolyticus	IAM 1077	BamN _x (AvaII)	GTC(Δ)CC	35 73 6 1 8	223,224,106
		BanI (HgiCI)	GTCGPyCC	25 57 1 3 9	244,244,209
		BanII (HgiJII)	GPUGCPyTC	7 57 2 0 2	244
		BanIII (ClaI)	ATCGAT	15 2 0 0 1	244
Bacillus brevis S	A. P. Zarubina	BbvSI	GCT(Δ)CC	specific methylase	266
Bacillus brevis	ATCC 9999	BbvI	GCAGC (8/12)	199 179 22 14 21	74,72,209, 91,91
Bacillus caldolyticus	A. Atkinson	BclII	TTCATCA	8 5 1 0 0	13
Bacillus centrosporus	A. A. Janulaitis	BcniI (CauII)	CC(C)TCG	114 97 0 1 10	113
Bacillus cereus	ATCC 14579	BceI4579	?	>10 ? ? ? ?	225
Bacillus cereus	ATCC 31293	BceFI (XnuDII)	CGCG	157 303 0 14 23	180
Bacillus cereus	IAM 1229	BceI229	?	>10 ? ? ? ?	225
Bacillus cereus	T. Ando	BceI70 (PstI)	CTGCAG	28 30 2 1 1	225
Bacillus cereus Rf sm st	T. Ando	BceR (EnuDII)	CGCG	157 303 0 14 23	225
Bacillus globigii	G. A. Wilson	BglI	GCNNNNfNGGC	29 20 1 0 3	51,279,9,262
Bacillus megaterium 899	B899	BglII	ATCATCT	6 11 0 0 0	51,279,184
Bacillus megaterium B205-3	T. Kaneko	Bme899	?	>5 ? ? ? ?	225
Bacillus megaterium	J. Upcroft	Bme205	?	>10 ? ? ? ?	225
		BmeI	?	>10 >20 4 ? ?	67

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c λ Ad2 SV40 ΦX PBR	References
<i>Bacillus pumilus</i> AHU1387A	T. Ando	BpuI	?	6 >30 2 ? ?	105
<i>Bacillus sphaericus</i>	IAM 1286	Bsp1286 (SduI)	G(A)cc(A)tc	38 105 4 3 10	225,175,211
<i>Bacillus sphaericus</i> R	P. Venetianer	BspRI (HaeIII)	GGTCC	149 216 18 11 22	126,268,129
<i>Bacillus stearo-thermophilus</i> NUB 36	N. Welker	BsmI	?	>30 >11 3 3 1	175
<i>Bacillus stearo-thermophilus</i> Cl	N. Welker	BatCI (HaeIII)	GGCC	149 216 18 11 22	136
<i>Bacillus stearo-thermophilus</i> Cll	N. Welker	BsaCI (HaeIII)	GGCC	149 216 18 11 22	136
<i>Bacillus stearo-thermophilus</i> G3	N. Welker	BatGI (BclI)	TGATCA	8 5 1 0 0	136
<i>Bacillus stearo-thermophilus</i> G6	N. Welker	BatGII (EcoRII)	CC(A)GG	71 136 17 2 6	136
<i>Bacillus stearo-thermophilus</i> H1	N. Welker	BsaGI (BstXI)	CCANNNNNTGG	13 10 1 3 0	136
<i>Bacillus stearo-thermophilus</i> H3	N. Welker	BsaGII (HhoI)	GATC	116 87 8 0 22	136
<i>Bacillus stearo-thermophilus</i> H4	N. Welker	BatHI (XhoI)	CTCGAG	1 6 0 1 0	136
<i>Bacillus stearo-thermophilus</i> P1	N. Welker	BsaHI (XhoI)	CTCGAG	1 6 0 1 0	136
<i>Bacillus stearo-thermophilus</i> P5	N. Welker	BsaHII (BaePI)	GTCGCGC	6 52 0 1 0	136,214
<i>Bacillus stearo-thermophilus</i> P6	N. Welker	BsaHI (BaePI)	GCGCGC	6 52 0 1 0	136
	N. Welker	BsaPI	?	>30 ? ? ? ?	136
	N. Welker	BsaPI	?	11 >20 ? 0 0	136
	N. Welker	BsaPII (Sau3A)	GATC	116 87 8 0 22	136
	N. Welker	BaePI	GCGCGC	6 52 0 1 0	136

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ X PBR	
Bacillus stearo-thermophilus F8	N. Welker	BspPI (MboI)	GATC	116 87 8 0 22	136
Bacillus stearo-thermophilus P9	N. Welker	BspPI (BspPI)	GCGCGC	6 52 0 1 0	136
Bacillus stearo-thermophilus T12	N. Welker	BatFI (BatXI)	CCANNNNNTGG	13 10 1 3 0	136
Bacillus stearo-thermophilus X1	N. Welker	BatXI	CCANNNNNTGG	13 10 1 3 0	136, 215
		BatXII (MboI)	GATC	116 87 8 0 22	136
Bacillus stearo-thermophilus 1503-4R	N. Welker	BatI (BamHI)	GTCATCC	5 3 1 0 1	31, 34
Bacillus stearo-thermophilus 240	A. Atkinson	BatAI	?	? ? ? ? ?	15
Bacillus stearo-thermophilus ET	N. Welker	BatEI	?	? ? ? ? ?	163
		BatEII	GTCNACC	13 10 0 0 0	163, 138
		BatEIII (MboI)	GATC	116 87 8 0 22	163, 77, 175
Bacillus stearo-thermophilus	ATCC 12980	BatPI (BatEII)	GTCNACC	13 10 0 0 0	186
Bacillus stearo-thermophilus	D. Comb	BatNI (EcoRII)	CC $\uparrow$ ($\downarrow$)GG	71 136 17 2 6	212
Bacillus stearo-thermophilus strain 822	T. Oshima	BaeI (HaeIII)	GGCC	149 216 18 11 22	229
		BaeII (HpaI)	GTTAAC	14 6 4 3 0	229
Bacillus subtilis strain R	T. Trautner	BauRI (HaeIII)	GCTCC	149 216 18 11 22	22, 21, 83
Bacillus subtilis Marburg 168	T. Ando	BauM (XhoI)	CTGAG	1 6 0 1 0	225, 117, -, 117
Bacillus subtilis	ATCC 6633	Bau6633	?	>20 ? ? ? ?	225
Bacillus subtilis	IAM 1076	Bau1076 (HaeIII)	GGCC	149 216 18 11 22	225
Bacillus subtilis	IAM 1114	Bau1114 (HaeIII)	GGCC	149 216 18 11 22	225

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				Ad2 λ	SV40 φX PBR
<i>Bacillus subtilis</i>	IAM 1247	Bau1247 (PstI)	CTGCAG	28 30	2 1 1 225,97
<i>Bacillus subtilis</i>	ATCC 14593	Bau1145	?	>20	? ? ? ? 225
<i>Bacillus subtilis</i>	IAM 1192	Bau1192I (HpaII)	CCGG	328 171	1 5 26 225,189
		Bau1192II (FnuDII)	CCGG	157 303	0 14 23 189
<i>Bacillus subtilis</i>	IAM 1193	Bau1193 (FnuDII)	CCGG	157 303	0 14 23 225,189
<i>Bacillus subtilis</i>	IAM 1231	BauFI (HpaII)	CCGG	328 171	1 5 26 225,189,117
		BauFII (FnuDII)	CCGG	157 303	0 14 23 189,189,-117
<i>Bacillus subtilis</i>	IAM 1259	Bau1259	?	>8	? ? ? ? 225
<i>Bacillus vulgatus</i>	OSB816	BvuI (HgiII)	GPuGCPyTC	7 57	2 0 2 7
<i>Bifidobacterium bifidum</i>	T. Khosaka	BbiI (PstI)	CTGCAG	28 30	2 1 1 124
YIT4007		BbiII (AcyI)	GPuGCPyC	40 44	0 7 6 124
		BbiIII (XhoI)	CTGCAG	1 6	0 1 0 124
		BbiIV	?	? ?	0 0 0 124
<i>Bifidobacterium breve</i>	H. Takahashi	BbeI (NarI)	GGCGCTC	1 20	0 2 4 125
YIT4006		BbeII	?	? ?	? ? ? 124
		?	?	? ?	? ? ? 124
<i>Bifidobacterium breve</i> S1	ATCC 15700	BbeAI (NarI)	GGCGCC	1 20	0 2 4 124
<i>Bifidobacterium breve</i> S50	ATCC 15698	BbeAII	?	? ?	? ? ? 124
<i>Bifidobacterium infantis</i> 659	ATCC 25962	BbiI	GGATC (4/5)	58 35	6 0 12 124
<i>Bifidobacterium infantis</i> S76e	ATCC 15702	BbSI (EcoRII)	CC(A)GG	71 136	17 2 6 124
		BbSII (NarI)	GGCGCC	1 20	0 2 4 124
<i>Bifidobacterium longum</i> E194b	ATCC 15707	BbGI	?	? ?	? ? ? 124

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c			References
				λ	Ad2	SV40 Φ X	
e	Bifidobacterium thermophilum RU326	BlnI (XhoI)	CTCGAG	1	6	0	1 0 124
		BlnII (BlnI)	GGATC	58	35	6	0 12 124
	Bordetella bronchiseptica	BbrI (HindIII)	AAGCTT	6	12	6	0 1 175
	Bordetella pertussis	BpeI (HindIII)	AAGCTT	6	12	6	0 1 79
	Brevibacterium albidum	BalI	TGGTCCA	18	17	0	0 1 68,68,259
	Brevibacterium luteum	BluI (XhoI)	CTCGAG	1	6	0	1 0 73
		BluII (HaeIII)	GGCC	149	216	18	11 22 263
	e Brevibacterium protophormiae	BprI	?	?	?	?	?
	Calothrix scopulorum	CacI (SacII)	CCGTCG	4	33	0	1 0 53
	Caryophanon latum L	ClaI	ATTCGAT	15	2	0	0 1 159
e	Caryophanon latum	ClaI	GGCC	149	216	18	11 22 236
		ClaII (HaeIII)	GG(^A)CC	35	73	6	1 8 236
	Caryophanon latum	CltI (HaeIII)	GGTCC	149	216	18	11 22 161
	Caryophanon latum RII	CltI	?	>20	?	?	?
	Caryophanon latum H7	CalI	?	14	?	?	?
	Caulobacter crescentus CB-13	CcrI	?	1	>10	0	1 1 251
		CcrII (XhoI)	CTCGAG	1	6	0	1 0 251
	Caulobacter fusiformis	CfuI (DpnI)	GATC	only cleaves methylated DNA			103
	Chloroflexus aurantiacus	CauI (AvaII)	GTC(^A)CC	35	73	6	1 8 14,167
		CauII	CCF(^G)GG	114	97	0	1 10 14,146,167
e		CauIII (PstI)	CTCGAG	28	30	2	1 1 8
	Chromatium vinosum	CynI (SmaI)	CCCTNAGG	2	7	0	0 0 82

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ X pBR	
<i>Chromobacterium violaceum</i>	ATCC 12472	<u>Cvi</u> I	?	? ? ? ? ?	57
<i>Citrobacter freundii</i> RFL2	A.A. Janulaitis	<u>Cfr</u> I	PyTGGCCPu	39 70 0 2 6	115
<i>Citrobacter freundii</i> RFL4	A.A. Janulaitis	<u>Cfr</u> 4I (<u>Asu</u> I)	GGNC	74 164 11 2 15	114
<i>Citrobacter freundii</i> RFL5	A.A. Janulaitis	<u>Cfr</u> 5I (<u>Eco</u> RII)	CC(Δ)GG	71 136 17 2 6	114
<i>Citrobacter freundii</i> RFL6	A.A. Janulaitis	<u>Cfr</u> 6I (<u>Pvu</u> II)	CAGCTG	15 24 3 0 1	114
<i>Citrobacter freundii</i> RFL7	A.A. Janulaitis	<u>Cfr</u> 7I (<u>Bst</u> EII)	GGTNACC	13 10 0 0 0	114
<i>Citrobacter freundii</i> RFL8	A.A. Janulaitis	<u>Cfr</u> 8I (<u>Asu</u> I)	GGNC	74 164 11 2 15	114
<i>Citrobacter freundii</i> RFL9	A.A. Janulaitis	<u>Cfr</u> 9I (<u>Sma</u> I)	CfCCGGG	3 12 0 0 0	114
<i>Citrobacter freundii</i> RFL10	A.A. Janulaitis	<u>Cfr</u> 10I	PUCGGEPy	61 40 1 0 7	114
<i>Citrobacter freundii</i> RFL11	A.A. Janulaitis	<u>Cfr</u> 11I (<u>Eco</u> RII)	CC(Δ)GG	71 136 17 2 6	114
<i>Citrobacter freundii</i> RFL13	A.A. Janulaitis	<u>Cfr</u> 13I (<u>Asu</u> I)	GGNC	74 164 11 2 15	114
<i>Citrobacter freundii</i> RFL14	A.A. Janulaitis	<u>Cfr</u> 14I (<u>Cfr</u> I)	PyTGGCCPu	39 70 0 2 6	114
<i>Clostridium formicoaceticum</i>	ATCC 23439	<u>Cfo</u> I (<u>Hha</u> I)	CGCG	215 375 2 18 31	155
<i>Clostridium histolyticum</i>	R. Hansen	<u>Ch</u> I	?	? ? ? ? ?	88
<i>Clostridium pasteurianum</i>	NRCC 33011	<u>Cpa</u> I (<u>Mbo</u> I)	GATC	116 87 8 0 22	268
<i>Clostridium perfringens</i>	R. Hansen	<u>Cpf</u> I (<u>Sau</u> 3A)	TGATC	116 87 8 0 22	88
<i>Corynebacterium humiferum</i>	ATCC 21108	<u>Chu</u> I (<u>Hind</u> III)	AAGCTT	6 12 6 0 1	57
<i>Corynebacterium petrophilum</i>	ATCC 19080	<u>Chu</u> II (<u>Hind</u> II)	GTPyPuAC	35 25 7 13 2	57
<i>Cystobacter velatus</i> Plv9		<u>Cps</u> I (<u>Bcl</u> I)	TGATCA	8 5 1 0 0	59
	H. Reichenbach	<u>Cye</u> I	?	? ? ? ? ?	161

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c					References
				λ	Ad2	SV40	ϕ X	PBR	
<i>Deinococcus radiophilus</i>	ATCC 27603	DraI (AbaIII)	TTTTAA	13	12	12	2	3	187
<i>Deinococcus radiophilus</i>		DraII	?	1	>10	3	?	3	88
<i>Deinococcus radiophilus</i>		DraIII	?	>12	>12	?	?	?	88
<i>Desulfovibrio desulfuricans</i> Norway strain	H. Peck	DdeI	CTTNA	104	97	20	14	8	155,69
		DdeII (XhoI)	CTCAG	1	6	0	1	0	175
		DdeI (BamHI)	GGATCC	5	3	1	0	1	154
<i>Desulfovibrio desulfuricans</i>	ATCC 27774	DpnI	CAATC	only cleaves methylated DNA					133,65,134
<i>Diplococcus pneumoniae</i>	S. Lacks	DpnII (HhoI)	GATC	116	87	8	0	22	133,134
<i>Diplococcus pneumoniae</i>	S. Lacks	EaeI (CfrI)	PyTGCCPu	39	70	0	2	6	277
<i>Enterobacter aerogenes</i>	P.R. Whitehead	EaePI (PstI)	CTCAG	28	30	2	1	1	180
<i>Enterobacter aerogenes</i>	ATCC 15038	EclI	?	14	?	?	?	?	89
<i>Enterobacter cloacae</i>	H. Hartmann	EclII (EcoRII)	CC(A) ₂ GG	71	136	17	2	6	89
		EaeI (BstEII)	GfGTNACC	13	10	0	0	0	96
	DSM 30056	EaeII (EcoRII)	CC(A) ₂ GG	71	136	17	2	6	175
<i>Enterobacter cloacae</i>	DSM 30060	EaeI (SaeII)	CCGCG	4	33	0	1	0	160,175
<i>Escherichia coli</i> RFL 24	A.A. Janulaitis	Eco24I (HglJII)	GPuGCPyC	7	57	2	0	2	107
<i>Escherichia coli</i> RFL 25	A.A. Janulaitis	Eco25I (HglJII)	GPuGCPyC	7	57	2	0	2	107
<i>Escherichia coli</i> RFL 26	A.A. Janulaitis	Eco26I (HglJII)	GPuGCPyC	7	57	2	0	2	107
<i>Escherichia coli</i> RFL 27	A.A. Janulaitis	Eco27I (EcoRII)	CC(A) ₂ GG	71	136	17	2	6	107
<i>Escherichia coli</i> RFL 32	A.A. Janulaitis	Eco32I (EcoRV)	GATATC	21	9	1	0	1	107
<i>Escherichia coli</i> RFL 35	A.A. Janulaitis	Eco35I (HglJII)	GPuGCPyC	7	57	2	0	2	107
<i>Escherichia coli</i> RFL 36	A.A. Janulaitis	Eco36I (PstI)	CTCAG	28	30	2	1	1	107

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ X DB8	
<i>Escherichia coli</i> RFL 38	A.A. Janulaitis	Eco38I (EcoRII)	CC($\downarrow$)GG	71 136 17 2 6	107
<i>Escherichia coli</i> RFL 39	A.A. Janulaitis	Eco39I (AseI)	GGCC	74 164 11 2 15	107
<i>Escherichia coli</i> RFL 40	A.A. Janulaitis	Eco40I (HgiIII)	GPUGCPYC	7 57 2 0 2	107
<i>Escherichia coli</i> RFL 41	A.A. Janulaitis	Eco41I (HgiIII)	GPUGCPYC	7 57 2 0 2	107
<i>Escherichia coli</i> RFL 47	A.A. Janulaitis	Eco47I (AvaII)	GG($\downarrow$)CC	35 73 6 1 8	112
<i>Escherichia coli</i> 2bT		Eco47II (AseI)	GGCC	74 164 11 2 15	112
<i>Escherichia coli</i> 2bT		Eco47III	AGCGT	2 13 1 0 4	112
<i>Escherichia coli</i> RFL 48	A.A. Janulaitis	Eco48I (PstI)	CTCAG	28 30 2 1 1	112
<i>Escherichia coli</i> RFL 49	A.A. Janulaitis	Eco49I (PstI)	CTCAG	28 30 2 1 1	112
<i>Escherichia coli</i> RFL 50	A.A. Janulaitis	Eco50I (HgiCI)	GGPyPucc	25 57 1 3 9	112
<i>Escherichia coli</i> 2bT	ICR 0020	EcoICRI (SacI)	GAECTC	2 16 0 0 0	245
<i>Escherichia coli</i> pDX1	A. Piekarowicz	EcoDXI	ATCA(N) ₇ ATTC	Type I 1 2 0	181
<i>Escherichia coli</i> J62 pLG74	L.I. Glatman	EcoRV	GATTC	21 9 1 0 1	123,123,210
<i>Escherichia coli</i> RY13	R.N. Yoshimori	EcoRI	GTAATC	5 5 1 0 1	80,92,80,50
<i>Escherichia coli</i> R245	R.N. Yoshimori	EcoRII	PUPAATPyPy	190 100 24 16 15	171
<i>Escherichia coli</i> 15T ⁻	T. Bickle	EcoA	TC($\downarrow$)GG	71 136 17 2 6	284,11,18; 284,18
<i>Escherichia coli</i> B	W. Arber	EcoB	*GAG(N) ₇ GTC ^{ah}	Type I 0 0 0	247,130
<i>Escherichia coli</i> K	M. Meselson	EcoK	TGA(N) ₈ TGCT	Type I 1 0 0	58,139,191; 140,265
<i>Escherichia coli</i> (PI)	K. Murray	EcoPI	AAC(N) ₆ TGC	Type I 0 0 2	164,10,120,85
<i>Escherichia coli</i> P15	W. Arber	EcoP15	AGACC	Type IIId 4 7 4	84,4,19, 20,4,90
			CAGCAG	Type IIId 12 5 7	193,86

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c				References
				λ	Ad2	SV40	PA	DBE
Flavobacterium okeanoicoites	IFO 12536	FokI	GGATG (9/13)	150	78	11	8	12 243
Fremyella diplosiphon	PCC 7601	FdiI (AvaII)	GTC(A) ₂ CC	35	73	6	1	8 261,241
		FdiII (MstI)	TCTCCA	15	17	0	1	4 261,241
Fusobacterium nucleatum A	M. Smith	FnuAI (HinfI)	GTATC	148	72	10	21	10 150
Fusobacterium nucleatum C	M. Smith	FnuAII (HboI)	GATC	116	87	8	0	22 150,175
Fusobacterium nucleatum D	M. Smith	FnuCI (MboI)	TGATC	116	87	8	0	22 150
		FnuDI (HaeIII)	GGTCC	149	216	18	11	22 150
		FnuDII	CGTCG	157	303	0	14	23 150
		FnuDIII (HhaI)	GCGTC	215	375	2	18	31 150
Fusobacterium nucleatum E	M. Smith	FnuEI (Sau3A)	TGATC	116	87	8	0	22 150
Fusobacterium nucleatum 48	M. Smith	Fnu48I	?	>50	?	?	>10	? 149
Fusobacterium nucleatum 4H	M. Smith	Fnu4HI	GCTNC	379	411	24	31	42 145
Gluconobacter dioxyaceticus	IAM 1814	GdiI (StuI)	AGGTCCT	6	11	7	1	0 263
		GdiII	PyTGCCG	21	53	0	2	5 263
Gluconobacter dioxyaceticus	IAM 1840	Gdoi (BamHI)	GGATCC	5	3	1	0	1 220
Ø Gluconobacter gluconicus	IFO 3285	Ggli	?	?	?	?	?	? 245
Ø Gluconobacter indutricus	IFO 3260	Gini (BamHI)	GGATCC	5	3	1	0	1 245
Gluconobacter oxydans sub. melonogenes	IAM 1836	GoxI (BamHI)	GGATCC	5	3	1	0	1 220
Ø Gluconobacter suboxydans H-15T	M.S. Loytsianskaya	GauI	CTCCAG	25	32	6	3	4 108
Ø Gluconobacter suboxydans	M.S. Loytsianskaya	Gabi (GauI)	CTCCAG	25	32	6	3	4 108

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ DBR	
Haemophilus aegyptius	ATCC 11116	HaeI	(λ)GCTCC(λ)	64 56 11 6 7	176
		HaeII	PuGCGCTPy	48 76 1 8 11	195,260
		HaeIII	GCTCC	149 216 18 11 22	165,21,157,157
Haemophilus aphrophilus	ATCC 19415	HaeI	?	>30 ? ? ? ?	175
		HaeII (HaeII)	CFCGG	328 171 1 5 26	254,246
		HaeI	GACGC (5/10)	102 87 0 14 11	254,26,242
Haemophilus gallinarum	ATCC 14385	HaeI	GGCC	149 216 18 11 22	175
Haemophilus haemoglobinophilus	ATCC 19416	HaeI (HaeIII)	GCTC	215 375 2 18 31	197,197,158
Haemophilus haemolyticus	ATCC 10014	HaeI	GANTC	148 72 10 21 10	156
		HaeII (HaeI)	GGCC	215 375 2 18 31	237,33
Haemophilus influenzae GU	J. Chirikjian	HaeIII (HaeI)	GGATG	150 78 11 8 12	237,176,256
		HaeIII (HaeIII)	AAGCTT	6 12 6 0 1	237
Haemophilus influenzae 173	J. Chirikjian	HaeIII (HaeIII)	GGCC	157 303 0 14 23	179
Haemophilus influenzae 1056	J. Stuy	HaeIII (HaeIII)	?	>30 >30 0 5 ?	179
		HaeIII (HaeIII)	AAGCTT	6 12 6 0 1	179
Haemophilus influenzae serotype b, 1076	J. Stuy	HaeIII (HaeIII)	GTPPuAC	35 25 7 13 2	179
Haemophilus influenzae serotype c, 1160	J. Stuy	HaeIII (HaeIII)	GTPPuAC	35 25 7 13 2	179
Haemophilus influenzae serotype c, 1161	J. Stuy	HaeIII (HaeIII)	GTPPuAC	35 25 7 13 2	179
Haemophilus influenzae serotype e	A. Piekawicz	HaeI (HaeIII)	CGAATC	Type IIIId 0 5 1	181
Haemophilus influenzae R _b	C.A. Hutchison	HaeIII (HaeIII)	AAGCTT	6 12 6 0 1	166,175
Haemophilus influenzae R _c	A. Landy, G. Leidy	HaeIII (HaeIII)	GTPPuAC	35 25 7 13 2	135

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c					References
				λ	Ad2	SV40 Φ X	PR8		
Haemophilus influenzae Rd (exo-mutant)	S. H. Goodgal	HindI	CAC		specific methylase				204; 205
		HindII	GTPyTPuAC	35	25	7	13	2	235; 122; 204; 205
		HindIII	ATAGCTT	6	12	6	0	1	178; 178; 204; 205
		HindIV	CAC		specific methylase				204; 205
Haemophilus influenzae Rf	C.A. Hutchison	HinfI	GTATC	148	72	10	21	10	166; 104; 173
		HinfII (HindIII)	AAGCTT	6	12	6	0	1	158
		HinfIII	CGAATC	type III ^d	0	5	1		121; 182
		HinHI (HaeII)	PuGCGCPy	48	76	1	8	11	254
Haemophilus influenzae P1	S. Shen	HinPII (BhaI)	GTGCG	215	375	2	18	31	222
Haemophilus influenzae S1	S. Shen	HinS1 (BhaI)	GCGC	215	375	2	18	31	222
Haemophilus influenzae S2	S. Shen	HinS2 (BhaI)	GCGC	215	375	2	18	31	222
Haemophilus influenzae JC9	A. Piekarowicz	HinJCI (HindII)	GTPyTPuAC	35	25	7	13	2	183
		HinJCII (HindIII)	AAGCTT	6	12	6	0	1	183
Haemophilus parahaemolyticus	C.A. Hutchison	HphI	GCTGA (8/7)	168	99	4	9	12	166; 127
Haemophilus parainfluenzae	J. Setlow	HpaI	GTTAAAC	14	6	4	3	0	221; 64; 1
		HpaII	CTCGG	328	171	1	5	26	221; 64; 157; 157
Haemophilus suis	ATCC 19417	HauI (HindIII)	ATAGCTT	6	12	6	0	1	175
Halococcus agglomeratus	ATCC 25862	HagI	?	?	?	?	?	?	189
Herpetosiphon giganteus HPI023	J.H. Parish	HgiaI	G(A)ec(A)TC	28	38	0	3	8	25
Herpetosiphon giganteus Hpg 5	H. Reichenbach	HgiBI (AvaII)	GTC(A)CC	35	73	6	1	8	95

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c λ Ad2 SV40 φX PBR	References
Herpetosiphon giganteus Hpg 9	H. Reichenbach	HgiCI	GTCPPuCC	25 57 1 3 9	95,131
		HgiCII (AvaII)	GTC(Δ) ¹ CC	35 73 6 1 8	95
		HgiCIII (SalI)	GTCGAC	2 3 0 0 1	95
Herpetosiphon giganteus Hpa2	H. Reichenbach	HgiDI (AcyI)	GPuTcGPYC	40 44 0 7 6	95,131
		HgiDII (SalI)	GTCGAC	2 3 0 0 1	95
Herpetosiphon giganteus Hpg 24	H. Reichenbach	HgiEI (AvaII)	GTC(Δ) ¹ CC	35 73 6 1 8	95
		HgiEII	ACC(N) ₆ GGT	14 10 1 1 2	95
Herpetosiphon giganteus Hpg 14	H. Reichenbach	HgiFI	?	? 15 ? ? ?	161
Herpetosiphon giganteus Hpa 1	H. Reichenbach	HgiGI (AcyI)	GPuTcGPYC	40 44 0 7 6	131
Herpetosiphon giganteus HP1049	J.H. Parish	HgiHI (HgiCI)	GTCPPuCC	25 57 1 3 9	277
		HgiHII (AcyI)	GPuTcGPYC	40 44 0 7 6	277
		HgiHIII (AvaII)	GTC(Δ) ¹ CC	35 73 6 1 8	277
Herpetosiphon giganteus HFS101	H. Foster	HgiJI	?	? ? ? ? ?	277
		HgiJII	GPuGCPyTC	7 57 2 0 2	277
Herpetosiphon giganteus Hpg 32	H. Reichenbach	HgiKI	?	>18 >20 ? ? ?	161
Klebsiella pneumoniae OX8	J. Davies	KpnI	GGTATTC	2 8 1 0 0	233,257
Mastigocladus laminosus	CCAP 1447/1	MlaI (ApuII)	TTTCGAA	7 1 0 0 0	52
θ Methanococcus aeolicus PL-15/H	K.O. Stetter	MaeI	CTTAG	13 54 12 3 5	217
θ		MaeII	ATCGT	143 83 0 19 10	217
θ		MaeIII	TGTNAC	156 118 14 17 17	217
Microbacterium thermosphactum	ATCC 11509	MthI (Sau3A)	GATC	116 87 8 0 22	136
θ Micrococcus aurantiacus	IFO 12422	MauI (PstI)	CTGCAG	28 30 2 1 1	245

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c References			
				λ	Ad2	SV40 Φ X	DBR
<i>Micrococcus luteus</i>	IFO 12992	MluI	ATCCGT	7	5	0	2 0 243
<i>Micrococcus radiodurans</i>	ATCC 13939	MraI (SaeII)	CCGCGG	4	33	0	1 0 273
<i>Micrococcus varians</i>	RPL 19	MvaI (BaiNI)	CC(A)GG	71	136	17	2 6 116
<i>Microcoleus species</i>	D. Comb	MstI	TCTGCA	15	17	0	1 4 41,72
		MstII (SauI)	CCCTNAGG	2	7	0	0 0 209
<i>Moraxella bovis</i>	ATCC 10900	MboI	TGATC	116	87	8	0 22 66
		MboII	GAAGA (8/7)	130	113	16	11 11 66,24,55
<i>Moraxella bovis</i>	ATCC 17947	MbvI	?	?	?	?	? ? 119
<i>Moraxella gluei</i> LG1	J. Davies	MglI	?	?	?	?	? ? 233
<i>Moraxella gluei</i> LG2	J. Davies	MglII	?	?	?	?	? ? 233
<i>Moraxella kingae</i>	ATCC 23331	MkII (HindIII)	AAGCTT	6	12	6	0 1 119
<i>Moraxella nonliquefaciens</i>	ATCC 19975	MnoI (HpaII)	CTCGG	328	171	1	5 26 175,6
		MnoII (MnnIII)	?	>10	>6	3	? ? 175
		MnoIII (MboI)	GATC	116	87	8	0 22 175
<i>Moraxella nonliquefaciens</i>	ATCC 17953	MnlI	CCTC (7/7)	262	397	51	34 26 285,209
<i>Moraxella nonliquefaciens</i>	ATCC 17954	MnnI (HindII)	GTPyPuAC	35	25	7	13 2 87
		MnnII (HaeIII)	GCCC	149	216	18	11 22 87
		MnnIII	?	>10	>6	3	? ? 87
		MnnIV (HhaI)	GCGC	215	375	2	18 31 87
<i>Moraxella nonliquefaciens</i>	ATCC 19996	MnlI (HaeIII)	GCCC	149	216	18	11 22 119
		MnlII (HpaII)	CCGG	328	171	1	5 26 119
<i>Moraxella osloensis</i>	ATCC 19976	MomI (MboI)	GATC	116	87	8	0 22 66

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c References						
				λ	Ad2	SV40 Φ X	DBR			
<i>Moraxella phenylpyruvica</i>	ATCC 17955	MphI (EcoRII)	CC(^A)GG * *	71	136	17	2	6	119	
<i>Moraxella</i> species	R.J. Roberts	MapiI (HpaII)	CfCGG	328	171	1	5	26	264,264,209,-118	
<i>Myxococcus stipitatus</i> Mxs2	H. Reichenbach	MsiI (XhoI)	CTCGAG	1	6	0	1	0	166,175	
		MsiII	?	?	?	?	?	?	161	
<i>Myxococcus virescens</i> V-2	H. Reichenbach	MviI	?	1	?	?	?	?	168	
		MviII	?	?	?	?	?	?	168	
<i>Neisseria caviae</i>	NRCC 31003	NcaiI (HinfI)	GANTC	148	72	10	21	10	270	
<i>Neisseria cinerea</i>	NRCC 31006	NciiI (CauII)	CC(^C)GGf	114	97	0	1	10	274,99	
8 <i>Neisseria cuniculi</i>	ATCC 14688	NcuiI (MboII)	GAAGA	130	113	16	11	11	28	
<i>Neisseria denitrificans</i>	NRCC 31009	NdeiI	CAATATG	7	2	2	0	1	275	
		NdeiII (MboI)	GATC	116	87	8	0	22	270	
<i>Neisseria flavescens</i>	NRCC 31011	NfliI (MboI)	GATC	116	87	8	0	22	270	
		NfliII	?	?	?	?	?	?	270	
		NfliIII	?	?	?	?	?	?	270	
<i>Neisseria gonorrhoea</i>	G. Wilson	NgoI (HaeII)	PuGCGCPy	48	76	1	8	11	280	
<i>Neisseria gonorrhoea</i>	CDC 66	NgoII (HaeIII)	GGCC	149	216	18	11	22	45,44	
<i>Neisseria gonorrhoea</i> KH 7764-45	L. Mayer	NgoIII (SacII)	CCGCGG	4	33	0	1	0	177	
8 <i>Neisseria lactamica</i>	NRCC 2118	NlaiI (HaeIII)	GGCC	149	216	18	11	22	190	
8		NlaiII (MboI)	GATC	116	87	8	0	22	190	
8		NlaiIII	CATGf	181	183	17	22	26	190	
8		NlaiV	GGfNCC	82	178	16	6	24	190	

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c					References
				λ	Ad2	SV40	ϕ X	PBR	
<i>Neisseria lactamica</i>	NRCC 31016	NlaSI (SacII)	CCGCG	4	33	0	1	0	29
<i>Neisseria mucosa</i>	ATCC 19693	NlaSII (AcyI)	GPuCGPyC	40	44	0	7	6	29
<i>Neisseria mucosa</i>	ATCC 19697	NmuSI (AauI)	GGNCC	74	164	11	2	15	39
<i>Neisseria mucosa</i>	ATCC 25996	NmuPI (NaeI)	GCCGCC	1	13	1	0	4	28
<i>Neisseria mucosa</i>		NmuPI (DpnI)	GATC	only cleaves methylated DNA					28
<i>Neisseria mucosa</i>	ATCC 25997	NmuPII (AauI)	GGNCC	74	164	11	2	15	28
<i>Neisseria mucosa</i>	NRCC 31013	NmuDI (DpnI)	GATC	only cleaves methylated DNA					28
<i>Neisseria ovis</i>	NRCC 31020	NmuI (NaeI)	GCCGCC	1	13	1	0	4	270
		NovI	?	?	?	?	?	?	270
		NovII (HinfI)	GATC	148	72	10	21	10	270
<i>Neisseria sicca</i>	ATCC 9913	NsiAI (Sau3A)	GATC	116	87	8	0	22	36
<i>Neisseria sicca</i>	ATCC 29256	NsiI (AvaIII)	ATGCAAT	14	9	3	0	0	38
<i>Neisseria sicca</i>	NRCC 31004	NsiHI (HinfI)	GATC	148	72	10	21	10	269
<i>Neisseria subflava</i>	ATCC 19243	NmuDI (DpnI)	GATC	only cleaves methylated DNA					28
<i>Neisseria subflava</i>	ATCC 14221	NmuI (MboI)	GATC	116	87	8	0	22	28
<i>Nocardia aerocolonigenes</i>	ATCC 23870	NaeI	GCCfGCC	1	13	1	0	4	43
<i>Nocardia amarae</i>	ATCC 27809	NamI (NarI)	GCGGCC	1	20	0	2	4	148
<i>Nocardia argentinensis</i>	ATCC 31306	NarI	GGfGCC	1	20	0	2	4	42
<i>Nocardia blackwellii</i>	ATCC 6846	NbII (PvuI)	CGATfCG	3	7	0	0	1	209
<i>Nocardia brasiliensis</i>	ATCC 27936	NbRI (NaeI)	GCCGCC	1	13	1	0	4	189
<i>Nocardia brasiliensis</i>	ATCC 19296	NbAI (NaeI)	GCCGCC	1	13	1	0	4	189
<i>Nocardia corallina</i>	ATCC 19070	NcoI	CfCATGG	4	20	3	0	0	136

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c				References	
				λ	Ad2	SV40 Φ X	DBR		
<i>Nocardia dassonvillei</i>	ATCC 21944	NdaI (NarI)	GGTCGCC	1	20	0	2	4	37
	ATCC 19150	NmiI (KpnI)	GGTACC	2	8	1	0	0	40
	ATCC 21507	NopI (SalI)	GTTGCAC	2	3	0	0	1	209
<i>Nocardia opaca</i>		NopII	?	?	?	?	?	?	136
	ATCC 14630	NotI	GGTCGCCG	0	7	0	0	0	17;216
	ATCC 14629	NocI (PstI)	CTGCAG	28	30	2	1	1	40
<i>Nocardia rubra</i>	ATCC 15906	NruI	TCGTGCA	5	5	0	2	1	40
<i>Nocardia uniformis</i>	ATCC 21806	NunI	?	?	?	?	?	?	136
		NunII (NarI)	GGTCGCC	1	20	0	2	4	136
		NapBI (ApuII)	TTCGAA	7	1	0	0	0	54
<i>Nostoc species</i>	PCC 6705	NapBII	C(A)GTC(T)G	75	95	4	5	6	54
		Nap(7524)I	PuCATGTPY	32	41	2	0	4	192
<i>Nostoc species</i>	PCC 7524	Nap(7524)II (SduI)	G(A)GC(A)TC	38	105	4	3	10	192
		Nap(7524)III (AvaI)	CTPYCEPUG	8	40	0	1	1	192
		Nap(7524)IV (ApuI)	GTCNCC	74	164	11	2	15	192
<i>Nostoc species</i>		Nap(7524)V (ApuII)	TTCGAA	7	1	0	0	0	192
	PCC 7413	NapBI (Nap(7524)I)	PuCATGTPY	32	41	2	0	4	54
		NapBII (AvaII)	GG(A)CC	35	73	6	1	8	54
<i>Oerskovia xanthineolytica</i>	R. Shekman	OxaI (ApuI)	AGCT	143	158	34	24	16	240
		OxaII	?	?	?	?	?	?	240
<i>Proteus vulgaris</i>	ATCC 13315	PvuI	CGATTGG	3	7	0	0	1	71
		PvuII	CAGTCG	15	24	3	0	1	71

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c				References
				λ	Ad2	SV40	ϕ X	DBR
<i>Providencia alcalifaciens</i>	ATCC 9886	<i>Pai</i> (<i>Hae</i> II)	GGCC	149	216	18	11	22 67
<i>Providencia stuartii</i> 164	J. Davies	<i>Pst</i> I	CTCCATC	28	30	2	1	1 233/27
<i>Pseudonabaena</i> species	ATCC 27263	<i>Psp</i> I (<i>Ama</i> I)	GCNCC	74	164	11	2	15 170
<i>Pseudomonas aeruginosa</i>	G.A. Jacoby	<i>Pae</i> R7 (<i>Xho</i> I)	CITCGAG	1	59	0	0	0 94,70
<i>Pseudomonas alkaligenes</i>	ATCC 12815	<i>Pai</i> II (<i>Hae</i> II)	GGCC	149	216	18	11	22 245
<i>Pseudomonas alkanolytica</i>	IFO 12319	<i>Pan</i> I (<i>Xho</i> I)	CITCGAG	1	6	0	1	0 245
<i>Pseudomonas facilis</i>	M. VanMontagu	<i>Pfa</i> I (<i>Sau</i> 3A)	GATC	116	87	8	0	22 264
<i>Pseudomonas fluorescens</i>	IFO 3507	<i>Pfl</i> II	?	?	?	?	?	? 245
<i>Pseudomonas glycinae</i>	J.V. Leary	<i>Pgl</i> I (<i>Nae</i> I)	GCCGCC	1	13	1	0	4 142
<i>Pseudomonas maltophilia</i>	D. Comb	<i>Pma</i> I (<i>Pst</i> I)	CTCCAG	28	30	2	1	1 209
<i>Pseudomonas putida</i> C-83	Toyoboseki Co.	<i>Ppu</i> I (<i>Hae</i> II)	GGCC	149	216	18	11	22 245
<i>Rhizobium leguminosarum</i> 300	J. Beringer	<i>Rle</i> I	?	6	>10	?	?	? 282
<i>Rhizobium lupini</i> 1	W. Heumann	<i>Rlu</i> I (<i>Nae</i> I)	GCCGCC	1	13	1	0	4 281,93/232
<i>Rhizobium meliloti</i>	J.L. Denarie	<i>Rme</i> I	?	8	>10	?	?	? 93
<i>Rhodococcus rhodochrous</i>	ATCC 14349	<i>Rrh</i> I (<i>Sal</i> I)	GTCCAC	2	3	0	0	1 189
<i>Rhodococcus rhodochrous</i>		<i>Rrh</i> II	?	?	?	?	?	? 189
<i>Rhodococcus rhodochrous</i>	ATCC 4276	<i>Rro</i> I (<i>Sal</i> I)	GTCCAC	2	3	0	0	1 189
<i>Rhodococcus</i> species	ATCC 13259	<i>Rhe</i> I (<i>Bam</i> HI)	GGATCC	5	3	1	0	1 103
<i>Rhodococcus</i> species	ATCC 19148	<i>Rhp</i> I (<i>Sal</i> I)	GTCCAC	2	3	0	0	1 103
<i>Rhodococcus</i> species		<i>Rho</i> II	?	?	?	?	?	? 103
<i>Rhodococcus</i> species	ATCC 21664	<i>Rhe</i> I (<i>Sal</i> I)	GTCCAC	2	3	0	0	1 103

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c				References
				λ	Ad2	SV40	ϕ X	
Rhodospirillum rubrum	J. Chirikjian	RrbI	?	?	4	5	1	144
Rhodopseudomonas sphaeroides	R. Lascelles	RspI (PvuI)	CGATCG	3	7	0	0	12
Rhodopseudomonas sphaeroides	S. Kaplan	RshI (PvuI)	CGATTCG	3	7	0	0	152
Rhodopseudomonas sphaeroides	S. Kaplan	RsaI	GTTC	113	83	12	11	153
Rhodopseudomonas sphaeroides	S. Kaplan	RarI (EcoRI)	GAATTC	5	5	1	0	63
Salmonella infantis	A. deWaard	SinI (AvaII)	GG($\frac{A}{C}$)CC	35	73	6	1	151
Serratia marcescens Sp	C. Mulder	SmaI	CCCTGG	3	12	0	0	81,56
Serratia species SAI	B. Torheim	SspI	?	?	?	?	?	258
Sphaerotilus natans C	A. Pope	SnaI	GTATAC	3	3	0	0	185
Sphaerotilus natans	ATCC 15291	SnaBI	TACfGA	1	0	0	0	16
Spiroplasma citri ASP2	M.A. Stephens	SciNI (HhaI)	CfCC	215	375	2	18	31 238
Staphylococcus aureus 3A	E.E. Stobberingh	Sau3A (HhoI)	TGATC	116	87	8	0	22 248
Staphylococcus aureus PS96	E.E. Stobberingh	Sau96I (AseI)	CfCNCC	74	164	11	2	15 249
Staphylococcus intermedius	ATCC 29663	SinMI (MboI)	GATC	116	87	8	0	22 28
Staphylococcus saprophyticus	ATCC 13518	SinMII	?	?	?	?	?	28
Streptococcus cremoris F	C. Daly	SsaI	?	>10	?	?	?	136
Streptococcus durans	A. Janulaitis	SscrFI	CCNCG	185	233	17	3	16 60
Streptococcus dysgalactiae	ATCC 9926	SduI	G($\frac{A}{T}$)GC($\frac{C}{T}$)C	38	105	4	3	10 111
Streptococcus faecalis var. zymogenes	R. Wu	SdyI (AseI)	CCNCC	74	164	11	2	15 189
Streptococcus faecalis GU	J. Chirikjian	SfaiI (HaeIII)	GGTC	149	216	18	11	22 283
Streptococcus faecalis ND547	D. Clewell	Sfagu I (HpaII)	CCGG	328	171	1	5	26 35
Streptococcus faecalis		Sfani	GCATC (5/9)	169	84	6	12	22 218

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ X PBR	
Streptomyces achromogenes	ATCC 12767	SacI	GACCTC	2 16 0 0 0 2	2
		SacII	CCGCTGG	4 33 0 1 0 2	2
		SacIII	?	>100 >100 ? ? ? 2	2
Streptomyces albus	LM 52766	SalPI (PstI)	CTGCAfG	28 30 2 1 1 32;30	
Streptomyces albus subspecies pathocidicus	KCC 80166	SgaI (XhoI)	CTCGAG	1 6 0 1 0 228	
Streptomyces albus G	J.M. Ghuyssen	SaII	GfTCGAC	2 3 0 0 0 1 3	
		SaII	?	>20 ? ? ? ? 3	
Streptomyces aureofaciens	J. Timko	SauI	CCfTNAGG	2 7 0 0 0 0 255	
Streptomyces bobill	ATCC 3310	SboI (SacII)	CCGCGG	4 33 0 1 0 228;252	
Streptomyces caespitosus	H. Takahashi	ScaI	AGTfACT	5 5 0 0 1 128;78	
Streptomyces cupidosporus	KCC 80316	Scul (XhoI)	CTCGAG	1 6 0 1 0 228	
Streptomyces exfoliatus	KCC 80030	SaxI (XhoI)	CTCGAG	1 6 0 1 0 228	
		SaxII	?	2 ? ? ? ? 228	
Streptomyces fimbriatus	ATCC 15051	SfII	GGCCNNNTNGGCC	0 3 1 0 0 189	
Streptomyces fradiae	ATCC 3355	Sfri (SacII)	CCGCGG	4 33 0 1 0 228;252	
Streptomyces ganmycicus	KCC 80759	SgaI (XhoI)	CTCGAG	1 6 0 1 0 228	
Streptomyces goshikiensis	KCC 80294	SgoI (XhoI)	CTCGAG	1 6 0 1 0 228	
Streptomyces griseus	ATCC 23345	SgrI	?	0 7 0 ? ? 2	
Streptomyces hygroscopicus	T. Yamaguchi	ShyTI	?	2 ? ? ? ? 228	
Streptomyces hygroscopicus	F. Walter	ShyI (SacII)	CCGCGG	4 33 0 1 0 271	

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c	References
				λ Ad2 SV40 ϕ 2 DBE	
<i>Streptomyces karnatakensis</i>	ATCC 25463	SkaI (NaeI)	CCGCGC	1 13 1 0 4	28
<i>Streptomyces lavendulae</i>	ATCC 8664	SkaII (PstI)	CTCCAG	28 30 2 1 1	28
<i>Streptomyces luteoreticuli</i>	KCC 80788	SLaI (XhoI)	CfTCGAG	1 6 0 1 0	253
<i>Streptomyces oderifer</i>	ATCC 6246	SLuI (XhoI)	CTCGAG	1 6 0 1 0	252
		SodI	?	? ? ? ? ?	136
		SodII	?	? ? ? ? ?	136
<i>Streptomyces phaeochromogenes</i>	F. Bolivar	bdhI	GCATGIC	6 8 2 0 1	62
<i>Streptomyces phaeochromogenes</i>	IFO 3108	SpaI (SphI)	GCATGC	6 8 2 0 1	245
<i>Streptomyces stanford</i>	S. Goff, A. Rambach	SatI (SacI)	GAGCTTC	2 16 0 0 0	75;169
		SatII (SacII)	CCGCTCG	4 33 0 1 0	75
		SatIII (SacIII)	?	>100 >100 ? ? ?	75
		SatIV (BclI)	TGATCA	8 5 1 0 0	98
<i>Streptomyces tubercidicus</i>	H. Takahashi	StuI	AGCTCT	6 11 7 1 0	227
<i>Streptovorticillium flavopetersicum</i>	Upjohn UC 5066	SEII (PstI)	CTGCATC	28 30 2 1 1	119
<i>Thermoplasma acidophilum</i>	D. Searcy	ThaI (EcoDII)	CGICG	157 303 0 14 23	162
<i>Thermopolyspora glauca</i>	ATCC 15345	TolI (SacII)	CCGCGG	4 33 0 1 0	74
<i>Thermus aquaticus</i> YTI	J.I. Harris	TaqI	TfCGA [*]	121 50 1 10 7	206;206;-;207
		TaqII	GACCGA(11/9) CACCCA(11/9)	28 36 1 2 6	175,5
<i>Thermus aquaticus</i>	S.A. Grachev	TaqXI (BstNI)	CCf(A)CG	71 136 17 2 6	76
<i>Thermus flavus</i> AT62	T. Oshima	TfII (TaqI)	TCCA	121 50 1 10 7	207
<i>Thermus thermophilus</i> HB8	T. Oshima	TthHB8 I (TaqI)	TcGA [*]	121 50 1 10 7	208;267;208, 267;207;207

Microorganism	Source	Enzyme ^a	Sequence ^b	Number of cleavage sites ^c λ Ad2 SV40 φX PBR	References
<i>Thermus thermophilus</i> strain 23 T. Oshima		TtrI (Tth111 I)	GACNNNGTC	2 12 0 0 1	231
<i>Thermus thermophilus</i> strain 110	Y. Oshima	TtgI (Tth111 I)	GACNNNGTC	2 12 0 0 1	231
<i>Thermus thermophilus</i> strain 111	T. Oshima	Tth111 I	GACNNNGTC	2 12 0 0 1	231
		Tth111 II	CAAPUCA	49 53 11 11 5	230
		Tth111 III	?	? ? ? ? ?	229
<i>Tolypothrix tenuis</i>	W. Siegelman	TtnI (HagIII)	GGCC	149 216 18 11 22	241
<i>Vibrio harveyi</i>	ATCC 14126	VhaI (HaeIII)	GGCC	149 216 18 11 22	103
<i>Xanthomonas amaranthicola</i>	ATCC 11645	XamI (SaiI)	GTCCAC	2 3 0 0 1	3
<i>Xanthomonas badrii</i>	ATCC 11672	XbaI	TTCAGA	1 5 0 0 0	287
<i>Xanthomonas holcicola</i>	ATCC 13461	XhoI	CTCCAG	1 6 0 1 0	73
		XhoII	PuTGATCPy	21 22 3 0 8	179,74
<i>Xanthomonas malvacearum</i>	ATCC 9924	XmaI (SmaI)	CTCCGG	3 12 0 0 0	56
		XmaII (PstI)	CTCCAG	28 30 2 1 1	56
		XmaIII	CTGGCC	2 19 0 0 1	132
<i>Xanthomonas manihotis</i> 7AS1	B-C. Lin	XmnI	GAANNNTTTC	24 5 0 3 2	147,189
<i>Xanthomonas nigromaculans</i>	ATCC 23390	XnuI (PvuI)	CGATCG	3 7 0 0 1	87
<i>Xanthomonas oryzae</i>	M. Ehrlich	XorI (PstI)	CTCCAG	28 30 2 1 1	272
		XorII (PvuI)	CGATTGG	3 7 0 0 1	272,71
<i>Xanthomonas papavericola</i>	ATCC 14180	XpaI (XhoI)	CTCCAG	1 6 0 1 0	73

Footnotes to Table

a. When two enzymes recognize the same sequence, i.e., are isoschizomers, the prototype (i.e., the first example isolated) is indicated in parentheses. Note that *MboI* is sensitive to *dam* methylation, whereas its isoschizomer *Sau3A* is not and *EcoRII* is sensitive to *dcm* methylation whereas its isoschizomer *BatNI* is not. For other isoschizomers of these two enzymes the corresponding prototype is indicated according to its methylation sensitivity.

b. Recognition sequences are written from 5' -> 3', only one strand being given, and the point of cleavage is indicated by an arrow (†). When no arrow appears, the precise cleavage site has not been determined. For example, *GATCC* is an abbreviation for

```
5' GTC A T C C 3'
3' C C T A GTC 5'
```

For enzymes such as *HgaI*, *MboII* etc., which cleave away from their recognition sequence the sites of cleavage are indicated in parentheses. For example *HgaI* CACGC(5/10) indicates cleavage as shown below

```
5'GACCCNNNN†      3'
3'CTCCNNNNNNNNNT5'
```

In all cases the recognition sequences are oriented so that the cleavage sites lie on their 3' side.

Bases appearing in parentheses signify that either base may occupy that position in the recognition sequence. Thus, *AccI* cleaves the sequences GTACAC, GTATAC, GTCGAC, and GTCTAC. Where known, the base modified by the corresponding specific methylase is indicated by an asterisk. A is N6-methyladenosine. C is 5-methylcytosine.

c. These columns indicate the frequency of cleavage by the various specific endonucleases on bacteriophage lambda DNA (λ), adenovirus-2 DNA (Ad2), simian virus 40 DNA (SV40), ϕ174 RF DNA and pBR322 DNA (pBR). In all cases the sites were derived by computer search of the complete sequences. These were obtained from GENBANK, except in the case of Adenovirus 2 where the complete sequence has been compiled from published results plus the unpublished results from the laboratories of U. Pettersson and R.J. Roberts.

d. *EcoPI*, *EcoPI5*, *HincI* and *HinfII* have characteristics intermediate between those of the Type I and Type II restriction endonucleases. They are designated Type III in accordance with the suggestion of Kauc and Piekarczyk (121).

e. Both *HinfIII* and *HincI* cleave about 25 bases 3' of the recognition sequence.

f. *NciI* leaves termini carrying a 3'-phosphate group (99).

g. *PaeRI* fails to cleave the *XhoI* site at 26.5% on the Ad2 genome (70).

h. The * placed under the T residue signifies that the A residue, on the complementary strand at that position, is modified by the *EcoA* methylase.

REFERENCES

1. Agarwal, K., unpublished observations.
2. Arrand, J.R., Myers, P.A. and Roberts, R.J., unpublished observations.
3. Arrand, J.R., Myers, P.A. and Roberts, R.J. *J. Mol. Biol.* **118**, 127-135 (1978).
4. Bachi, B., Reiser, J. and Pirrotta, V. *J. Mol. Biol.* **128**, 143-163 (1979).
5. Barker, D., Hoff, M., Oliphant, A. and White, R. *Nucleic Acids Res.* in press.
6. Baumstark, B.R., Roberts, R.J. and RajBhandary, U.L. *J. Biol. Chem.* **254**, 8943-8950 (1979).
7. Beaty, J.S., McLean-Bowen, C.A. and Brown, L.R. *Gene* **18**, 61-67 (1982).
8. Bennett, S.P. and Halford, S.E., unpublished observations.
9. Bickle, T.A. and Ineichen, K. *Gene* **2**, 205-212 (1980).
10. Bickle, T., Yuan, R., Pirrotta, V. and Ineichen, K., unpublished observations.
11. Bigger, C.H., Murray, K. and Murray, N.E. *Nature New Biology* **244**, 7-10 (1973).
12. Bingham, A.H.A., Atkinson, A. and Darbyshire, J., unpublished observations.
13. Bingham, A.H.A., Atkinson, T., Sciaky, D. and Roberts, R.J. *Nucleic Acids Res.* **5**, 3457-3467 (1978).
14. Bingham, A.H.A. and Darbyshire, J. *Gene* **18**, 87-91 (1982).
15. Bingham, A.H.A., Sharp, R.J. and Atkinson, T., unpublished observations.
16. Borsetti, R., Grandoni, R. and Schildkraut, I., unpublished observations.
17. Borsetti, R., Wise, D. and Schildkraut, I., unpublished observations.
18. Boyer, H.W., Chow, L.T., Dugaiczky, A., Hedgpeth, J. and Goodman, H.M. *Nature New Biology* **244**, 40-43 (1973).
19. Brockes, J.P. *Biochem. J.* **133**, 629-633 (1973).
20. Brockes, J.P., Brown, P.R. and Murray, K. *Biochem. J.* **127**, 1-10 (1972).
21. Bron, S. and Murray, K. *Mol. Gen. Genet.* **143**, 25-33 (1975).
22. Bron, S., Murray, K. and Trautner, T.A. *Mol. Gen. Genet.* **143**, 13-23 (1975).

-
23. Brown, N.L., unpublished observations.
 24. Brown, N.L., Hutchison, C.A. III and Smith, M. J. Mol. Biol. **140**, 143-148 (1980).
 25. Brown, N.L., McClelland, M. and Whitehead, P.R. Gene **2**, 49-68 (1980).
 26. Brown, N.L. and Smith, M. Proc. Natl. Acad. Sci. USA **74**, 3213-3216 (1977).
 27. Brown, N.L. and Smith, M. FEBS Letters, **65**, 284-287 (1976).
 28. Camp, R. and Schildkraut, I., unpublished observations.
 29. Camp, R. and Visentin, L.P., unpublished observations.
 30. Carter, J.A., Chater, K.F., Bruton, C.J. and Brown, N.L. Nucleic Acids Res. **8**, 4943-4954 (1980).
 31. Catterall, J.F. and Welker, N.E. J. Bacteriol. **129**, 1110-1120 (1977).
 32. Chater, K.F. Nucleic Acids Res. **4**, 1989-1998 (1977).
 33. Chirikjian, J.G., George, A. and Smith, L.A. Fed. Proc. **37**, 1415 (1978).
 34. Clarke, C.M. and Hartley, B.S. Biochem. J. **177**, 49-62 (1979).
 35. Coll, E. and Chirikjian, J., unpublished observations.
 36. Comb, D.G., unpublished observations.
 37. Comb, D.G., Hess, E.J. and Wilson, G., unpublished observations.
 38. Comb, D.G., Parker, P., Grandoni, R. and Schildkraut, I., unpublished observations.
 39. Comb, D.G., Parker, P. and Schildkraut, I., unpublished observations.
 40. Comb, D.G. and Schildkraut, I., unpublished observations.
 41. Comb, D.G., Schildkraut, I. and Roberts, R.J., unpublished observations.
 42. Comb, D.G., Schildkraut, I., Wilson, G. and Greenough, L., unpublished observations.
 43. Comb, D.G. and Wilson, G., unpublished observations.
 44. Clanton, D.J., Riggsby, W.S. and Miller, R.V. J. Bacteriol. **137**, 1299-1307 (1979).
 45. Clanton, D.J., Woodward, J.M. and Miller, R.V. J. Bacteriol. **135**, 270-273 (1978).
 46. DeWaard, A. and Duyvesteyn, M. Arch. Microbiol. **128**, 242-247 (1980).
-

47. DeWaard, A., Korsuize, J., van Beveren, C.P. and Maat, J. FEBS Letters **96**, 106-110 (1978).
48. DeWaard, A., van Beveren, C.P., Duyvesteyn, M. and van Ormondt, H. FEBS Letters **101**, 71-76 (1979).
49. DiLauro, R., unpublished observations.
50. Dugaiczky, A., Hedgpeth, J., Boyer, H.W. and Goodman, H.M. Biochemistry **13**, 503-512 (1974).
51. Duncan, C.H., Wilson, G.A. and Young, F.E. J. Bacteriol. **134**, 338-344 (1978).
52. Duyvesteyn, M.G.C. and deWaard, A. FEBS Letters **111**, 423-426 (1980).
53. Duyvesteyn, M.G.C., Korsuize, J. and deWaard, A. Plant Mol. Biol. **1**, 75-79 (1981).
54. Duyvesteyn, M.G.C., Reaston, J. and deWaard, A., unpublished observations.
55. Endow, S.A. J. Mol. Biol. **114**, 441-449 (1977).
56. Endow, S.A. and Roberts, R.J. J. Mol. Biol. **112**, 521-529 (1977).
57. Endow, S.A. and Roberts, R.J., unpublished observations.
58. Eskin, B. and Linn, S. J. Biol. Chem. **247**, 6183-6191 (1972).
59. Fisherman, J., Gingeras, T.R. and Roberts, R.J., unpublished observations.
60. Fitzgerald, G. and Daly, C., unpublished observations.
61. Fuchs, C., Rosenfold, E.C., Honigman, A. and Szybalski, W. Gene **4**, 1-23 (1978).
62. Fuchs, L.Y., Covarrubias, L., Escalante, L., Sanchez, S. and Bolivar, F. Gene **10**, 39-46 (1980).
63. Gardner, J.F., Cohen, L.K., Lynn, S.P. and Kaplan, S., unpublished observations.
64. Garfin, D.E. and Goodman, H.M. Biochem. Biophys. Res. Comm. **59**, 108-116 (1974).
65. Geier, G.E. and Modrich, P. J. Biol. Chem. **254**, 1408-1413 (1979).
66. Gelinas, R.E., Myers, P.A. and Roberts, R.J. J. Mol. Biol. **114**, 169-179 (1977).
67. Gelinas, R.E., Myers, P.A. and Roberts, R.J., unpublished observations.
68. Gelinas, R.E., Myers, P.A., Weiss, G.A., Murray, K. and Roberts, R.J. J. Mol. Biol. **114**, 433-440 (1977).

69. Gelinas, R.E. and Roberts, R.J., unpublished observations.
70. Gingeras, T.R. and Brooks, J.E. Proc. Natl. Acad. Sci. USA **80**, 402-406 (1983).
71. Gingeras, T.R., Greenough, L., Schildkraut, I. and Roberts, R.J. Nucleic Acids Res. **9**, 4525-4536 (1981).
72. Gingeras, T.R., Milazzo, J.P. and Roberts, R.J. Nucleic Acids Res. **5**, 4105-4127 (1979).
73. Gingeras, T.R., Myers, P.A., Olson, J.A., Hanberg, F.A. and Roberts, R.J. J. Mol. Biol. **118**, 113-122 (1978).
74. Gingeras, T.R. and Roberts, R.J., unpublished observations.
75. Goff, S.P. and Rambach, A. Gene **3**, 347-352 (1978) and unpublished observations.
76. Grachev, S.A., Mamaev, S.V., Gurevich, A.I., Igoshin, A.V., Kolosov, M.N. and Slyusarenko, A.G. Bioorg. Khim. **7**, 628-630 (1981).
77. Grandoni, R.P. and Comb, D., unpublished observations.
78. Grandoni, R.P. and Schildkraut, I., unpublished observations.
79. Greenaway, P.J. Biochem. Biophys. Res. Comm. **95**, 1282-1287 (1980).
80. Greene, P.J., Betlach, M.C., Boyer, H.W. and Goodman, H.M. Methods Mol. Biol. **7**, 87-111 (1974).
81. Greene, R. and Mulder, C., unpublished observations.
82. Grosveld, G.C. Gene, in press.
83. Gunthert, U., Storm, K. and Bald, R. Eur. J. Biochem. **90**, 581-583 (1978).
84. Haberman, A. J. Mol. Biol. **89**, 545-563 (1974).
85. Haberman, A., Heywood, J. and Meselson, M. Proc. Natl. Acad. Sci. USA **69**, 3138-3141 (1972).
86. Hadi, S.M., Bachi, B., Shepherd, J.C.W., Yuan, R., Ineichen, K. and Bickle, T.A. J. Mol. Biol. **134**, 655-666 (1979).
87. Hanberg, F., Myers, P.A. and Roberts, R.J., unpublished observations.
88. Hansen, R., unpublished observations.
89. Hartmann, H. and Goebel, W. FEBS Letters **80**, 285-287 (1977).
90. Hattman, S., Brooks, J.E. and Masurekar, M. J. Mol. Biol. **126**, 367-380 (1978).
91. Hattman, S., Keisler, T. and Gottehrer, A. J. Mol. Biol. **124**, 701-711 (1978).

92. Hedgpeth, J., Goodman, H.M. and Boyer, H.W. Proc. Natl. Acad. Sci. USA **69**, 3448-3452 (1972).
93. Heumann, W. Curr. Top. Microbiol. Immunol. **88**, 1-24 (1979).
94. Hinkle, N.F. and Miller, R.V. Plasmid **2**, 387-393 (1979).
95. Hobom, G., Mayer, H. and Schutte, H., unpublished observations.
96. Hobom, G., Schwarz, E., Melzer, M. and Mayer, H. Nucleic Acids Res. **2**, 4823-4832 (1981).
97. Hoshino, T., Uozumi, T., Horinouchi, S., Ozaki, A., Beppu, T. and Arima, K. Biochim. Biophys. Acta **479**, 367-369 (1977).
98. Hu, A.W., Kuebbing, D. and Blakesley, R.J. Fed. Proc. **38**, 780 (1978) and unpublished observations.
99. Hu, A.W. and Marschel, A.H., unpublished observations.
100. Hughes, S.G., Bruce, T. and Murray, K. Biochem. J. **185**, 59-63 (1980).
101. Hughes, S.G., Bruce, T. and Murray, K., unpublished observations.
102. Hughes, S.G. and Murray, K. Biochem. J. **185**, 65-75 (1980).
103. Hurlin, P. and Schildkraut, I., unpublished observations.
104. Hutchison, C.A. and Barrell, B.G., unpublished observations.
105. Ikawa, S., Shibata, T. and Ando, T. J. Biochem. (Tokyo) **80**, 1457-1460 (1976).
106. Ikawa, S., Shibata, T. and Ando, T. Agric. Biol. Chem. **43**, 873-875 (1979).
107. Janulaitis, A. and Bitinaite, J., unpublished observations.
108. Janulaitis, A., Bitinaite, J. and Jaskelaviciene, B., FEBS Letters, **151**, 243-247 (1983).
109. Janulaitis, A., Klimasauskas, S., Petrusyte, M. and Butkus, V., FEBS Letters, **161**, 131-134 (1983).
110. Janulaitis, A.A., Marcinkeviciene, L.U. and Petrusyte, M.P. Dokl. Akad. Nauk. SSSR **577**, 241-244 (1982).
111. Janulaitis, A., Marcinkeviciene, L., Petrusyte, M. and Mironov, A. FEBS Letters, **134**, 172-174 (1981).
112. Janulaitis, A.A. and Petrusyte, M., unpublished observations.
113. Janulaitis, A.A., Petrusyte, M.A., Jaskelaviciene, B.P., Krayev, A.S., Skryabin, K.G. and Bayev, A.A. FEBS Letters, **137**, 178-180 (1982).
114. Janulaitis, A.A., Stakenas, P.S., Bitinaite, J.B. and Jaskelaviciene, B.P. Dokl. Akad. Nauk. SSSR, in press.

115. Janulaitis, A.A., Stakenas, P.J., Jaskeleviciene, B.P., Lebedenko, E.N. and Berlin, Y.A. Bioorg. Khim. **6**, 1746-1748 (1980).
116. Janulaitis, A.A., Vaitkevicius, D., Puntezis, S. and Jalekeviciene, B., unpublished results.
117. Jentsch, S. J. Bacteriol. **156**, 800-808 1983.
118. Jentsch, S., Gunthert, U. and Trautner, T.A. Nucleic Acids Res. **12**, 2753-2759 (1981).
119. Jiang, B.D. and Myers, P., unpublished observations.
120. Kan, N.C., Lautenberger, J.A., Edgell, M.H. and Hutchison, C.A. III. J. Mol. Biol. **130**, 191-209 (1979).
121. Kauc, L. and Piekarowicz, A. Eur. J. Biochem. **92**, 417-426 (1978).
122. Kelly, T.J., Jr. and Smith, H.O. J. Mol. Biol. **51**, 393-409 (1970).
123. Kholmina, G.V., Rebentish, B.A., Skoblov, Y.S., Mironov, A.A., Yankovsky, N.K., Kozlov, Y.I., Glatman, L.I., Moroz, A.F. and Debabov, V.G. Dokl. Akad. Nauk. SSSR **253**, 495-497 (1980).
124. Khosaka, T., unpublished results.
125. Khosaka, T., Sakurai, T., Takahashi, H. and Saito, H. Gene, in press.
126. Kiss, A., Sain, B., Csordas-Toth, E. and Venetianer, P. Gene **1**, 323-329 (1977).
127. Kleid, D., Humayun, Z., Jeffrey, A. and Ptashne, M. Proc. Natl. Acad. Sci. USA **73**, 293-297 (1976).
128. Kojima, H., Takahashi, H. and Saito, H., unpublished results.
129. Koncz, C., Kiss, A. and Venetianer, P. Eur. J. Biochem. **89**, 523-529 (1978).
130. Kroger, M. and Hobom, G. Nucleic Acids Res. **12**, 887-899 (1984).
131. Kroger, M., Mayer, H., Schutte, H. and Hobom, G., unpublished observations.
132. Kunkel, L.M., Silberklang, M. and McCarthy, B.J. J. Mol. Biol. **132**, 133-139 (1979).
133. Lacks, S. and Greenberg, B. J. Biol. Chem. **250**, 4060-4066 (1975).
134. Lacks, S. and Greenberg, B. J. Mol. Biol. **114**, 153-168 (1977).
135. Landy, A., Ruedisueli, E., Robinson, L., Foeller, C. and Ross, W. Biochemistry **13**, 2134-2142 (1974).
136. Langdale, J.A., Myers, P.A. and Roberts, R.J., unpublished results.

137. Lau, R.H. and Doolittle, W.F. FEBS Letters **121**, 200-202 (1980).
138. Lautenberger, J.A., Edgell, M.H. and Hutchison, C.A. III. Gene **12**, 171-174 (1980).
139. Lautenberger, J.A., Kan, N.C., Lackey, D., Linn, S., Edgell, M.H. and Hutchison, C.A. III. Proc. Natl. Acad. Sci. USA **75**, 2271-2275 (1978).
140. Lautenberger, J.A. and Linn, S. J. Biol. Chem. **247**, 6176-6182 (1972).
141. Lautenberger, J.A., White, C.T., Haigwood, N.L., Edgell, M.H. and Hutchinson, C.A. III. Gene **2**, 213-231 (1980).
142. Leary, J.V., unpublished observations.
143. LeBon, J.M., Kado, C., Rosenthal, L.J. and Chirikjian, J. Proc. Natl. Acad. Sci. USA **75**, 4097-4101 (1978).
144. LeBon, J.M., LeBon, T., Blakesley, R. and Chirikjian, J., unpublished observations.
145. Leung, D.W., Lui, A.C.P., Merilees, H., McBride, B.C. and Smith, M. Nucleic Acids Res. **6**, 17-25 (1979).
146. Levi, C. and Bickle, T., unpublished observations.
147. Lin, B-C., Chien, M-C. and Lou, S-Y. Nucleic Acids Res. **8**, 6189-6198 (1980).
148. Lin, P-M. and Roberts, R.J., unpublished observations.
149. Lui, A.C.P., McBride, B.C. and Smith, M., unpublished observations.
150. Lui, A.C.P., McBride, B.C., Vovis, G.F. and Smith, M. Nucleic Acids Res. **6**, 1-15 (1979).
151. Lupker, H.S.C. and Dekker, B.M.M. Biochim. Biophys. Acta **654**, 297-299 (1981).
152. Lynn, S.P., Cohen, L.K., Gardner, J.F. and Kaplan, S. J. Bacteriol. **138**, 505-509 (1979).
153. Lynn, S.P., Cohen, L.K., Kaplan, S. and Gardner, J.F. J. Bacteriol. **142**, 380-383 (1980).
154. Makula, R.A., unpublished observations.
155. Makula, R.A. and Meagher, R.B. Nucleic Acids Res. **8**, 3125-3131 (1980).
156. Mann, M.B., Rao, R.N. and Smith, H.O. Gene **3**, 97-112 (1978).
157. Mann, M.B. and Smith, H.O. Nucleic Acids Res. **4**, 4211-4221 (1977).
158. Mann, M.B. and Smith, H.O., unpublished observations.
159. Mayer, H., Grosschedl, R., Schutte, H. and Hobom, G. Nucleic

Acids Res. **9**, 4833-4845 (1981).

160. Mayer, H. and Klaar, J., unpublished observations.
161. Mayer, H. and Schutte, H., unpublished observations.
162. McConnell, D.J., Searcy, D.G. and Sutcliffe, J.G. Nucleic Acids Res. **5**, 1729-1739 (1978).
163. Meagher, R.B., unpublished observations.
164. Meselson, M. and Yuan, R. Nature **217**, 1110-1114 (1968).
165. Middleton, J.H., Edgell, M.H. and Hutchison, C.A. III. J. Virol. **10**, 42-50 (1972).
166. Middleton, J.H., Stankus, P.V., Edgell, M.H. and Hutchison, C.A. III, unpublished observations.
167. Molemans, F., van Emmelo, J. and Fiers, W. Gene **18**, 93-96 (1982).
168. Morris, D.W. and Parish, J.H. Arch. Microbiol. **108**, 227-230 (1976).
169. Muller, F., Stoffel, S. and Clarkson, S.G., unpublished observations.
170. Mulligan, B.J. and Szekeres, M., unpublished results.
171. Murray, K., Brown, J.S. and Bruce, S.A., unpublished observations.
172. Murray, K., Hughes, S.G., Brown, J.S. and Bruce, S.A. Biochem. J. **159**, 317-322 (1976).
173. Murray, K. and Morrison, A., unpublished observations.
174. Murray, K., Morrison, A., Cooke, H.W. and Roberts, R.J., unpublished observations.
175. Myers, P.A. and Roberts, R.J., unpublished observations.
176. Nardone, G. and Blakesley, R. Fed. Proc. **40**, 1848 (1981).
177. Norlander, L., Davies, J.K., Hagblom, P., and Normark, S. J. Bacteriol. **145**, 788-795 (1981).
178. Old, R., Murray, K. and Roizes, G. J. Mol. Biol. **92**, 331-339 (1975).
179. Olson, J.A., Myers, P.A. and Roberts, R.J., unpublished observations.
180. Parker, P. and Schildkraut, I., unpublished observations.
181. Piekarowicz, A., unpublished observations.
182. Piekarowicz, A., Bickle, T.A., Shepherd, J.C.W. and Ineichen, K. In press.

183. Piekarowicz, A., Stasiak, A. and Stanczak, J. Acta Microbiol. Pol. **29**, 151-156 (1980).
184. Pirrotta, V. Nucleic Acids Res. **3**, 1747-1760 (1976).
185. Pope, A., Lynn, S.P. and Gardner, J.F., unpublished observations.
186. Pugatsch, T. and Weber, H. Nucleic Acids Res. **7**, 1429-1444 (1979).
187. Purvis, I.J. and Moseley, B.E.B. Nucleic Acids Res. **11**, 5467-5474 (1983).
188. Qiang, B-Q., unpublished observations.
189. Qiang, B-Q. and Schildkraut, I., unpublished observations.
190. Qiang, B-Q., Schildkraut, I. and Visentin, L., unpublished observations.
191. Ravetch, J.V., Horiuchi, K. and Zinder, N.D. Proc. Natl. Acad. Sci. USA **75**, 2266-2270 (1978).
192. Reaston, J., Duyvesteyn, M.G.C. and deWaard, A. Gene **20**, 103-110 (1982).
193. Reiser, J. and Yuan, R. J. Biol. Chem. **252**, 451-456 (1977).
194. Roberts, R.J. Nucleic Acids Res. **11**, r135-r167 (1983)
195. Roberts, R.J., Breitmeyer, J.B., Tabachnik, N.F. and Myers, P.A. J. Mol. Biol. **91**, 121-123 (1975).
196. Roberts, R.J., Myers, P.A., Morrison, A., and Murray, K. J. Mol. Biol. **102**, 157-165 (1976).
197. Roberts, R.J., Myers, P.A., Morrison, A. and Murray, K. J. Mol. Biol. **103**, 199-208 (1976).
198. Roberts, R.J., Wilson, G.A. and Young, F.E. Nature **265**, 82-84 (1977).
199. Roizes, G., Nardeux, P-C. and Monier, R. FEBS Letters **104**, 39-44 (1979).
200. Roizes, G., Pages, M., Lecou, C., Patillon, M. and Kovoor, A. Gene **6**, 43-50 (1979).
201. Roizes, G., Patillon, M. and Kovoor, A. FEBS Letters **82**, 69-70 (1977).
202. Rosenvold, E.C., unpublished observations.
203. Rosenvold, E.C. and Szybalski, W., unpublished observations, cited in Gene **7**, 217-270 (1979).
204. Roy, P.H. and Smith, H.O. J. Mol. Biol. **81**, 427-444 (1973).
205. Roy, P.H. and Smith, H.O. J. Mol. Biol. **81**, 445-459 (1973).

-
206. Sato, S., Hutchison, C.A. and Harris, J.I. Proc. Natl. Acad. Sci. USA **74**, 542-546 (1977).
207. Sato, S., Nakazawa, K. and Shinomiya, T. J. Biochem. **88**, 737-747 (1980).
208. Sato, S. and Shinomiya, T. J. Biochem. **84**, 1319-1321 (1978).
209. Schildkraut, I., unpublished observations.
210. Schildkraut, I., Banner, D.B., Rhodes, C.S. and Parekh, S. Gene, in press.
211. Schildkraut, I. and Christ, C., unpublished observations.
212. Schildkraut, I. and Comb, D., unpublished observations.
213. Schildkraut, I., Grandoni, C. and Comb, D., unpublished observations.
214. Schildkraut, I. and Greenough, L., unpublished observations.
215. Schildkraut, I. and Wise, R., unpublished observations.
216. Schildkraut, I. Wise, R., Borsetti, R. and Qiang, B.-Q., unpublished observations.
217. Schmid, K., Thomm, M., Laminet, A., Laue, F.G., Kessler, C., Stetter, K. and Schmitt, R. Nucleic Acids Res. in press.
218. Sciaky, D. and Roberts, R.J., unpublished observations.
219. Seurinck, J., van de Voorde, A. and van Montagu, M. Nucleic Acids Res. **11**, 4409-4415 (1983).
220. Seurinck, J. and van Montagu, M., unpublished observations.
221. Sharp, P.A., Sugden, B. and Sambrook, J. Biochemistry **12**, 3055-3063 (1973).
222. Shen, S., Li, Q, Yan, P., Zhou, B., Ye, S., Lu, Y. and Wang, D. Sci. Sin. **23**, 1435-1442 (1980)
223. Shibata, T. and Ando, T. Mol. Gen. Genetics **138**, 269-379 (1975).
224. Shibata, T. and Ando, T. Biochim. Biophys. Acta **442**, 184-196 (1976).
225. Shibata, T., Ikawa, S., Kim, C. and Ando, T. J. Bacteriol. **128**, 473-476 (1976).
226. Shimatake, H. and Rosenberg, M., unpublished observations.
227. Shimotsu, H., Takahashi, H. and Saito, H. Gene **11**, 219-225 (1980).
228. Shimotsu, H., Takahashi, H. and Saito, H. Agric. Biol. Chem. **44**, 1665-1666 (1980).
229. Shinomiya, T., unpublished observations.
-

230. Shinomiya, T., Kobayashi, M. and Sato, S. Nucleic Acids Res., **8**, 3275-3285 (1980).
231. Shinomiya, T. and Sato, S. Nucleic Acids Res. **8**, 43-56 (1980).
232. Sievert, U. and Rosch, A., unpublished observations.
233. Smith, D.I., Blattner, F.R. and Davies, J. Nucleic Acids Res. **3**, 343-353 (1976).
234. Smith, H.O. and Nathans, D. J. Mol. Biol. **81**, 419-423 (1973).
235. Smith, H.O. and Wilcox, K.W. J. Mol. Biol. **51**, 379-391 (1970).
236. Smith, J. and Comb, D., unpublished observations.
237. Smith, L., Blakesley, R. and Chirikjian, J., unpublished observations.
238. Stephens, M.A., unpublished observations.
239. Stobberingh, E.E., Schiphof, R. and Sussenbach, J.S. J. Bacteriol. **131**, 645-649 (1977).
240. Stotz, A. and Philippson, P., unpublished observations.
241. Streips, U. and Golemboski, B., unpublished observations.
242. Sugisaki, H. Gene **3**, 17-28 (1978).
243. Sugisaki, H. and Kanazawa, S. Gene, in press.
244. Sugisaki, H., Maekawa, Y., Kanazawa, S. and Takanami, M. Nucleic Acids Res. **10**, 5747-5752 (1982).
245. Sugisaki, H., Maekawa, Y., Kanazawa, S. and Takanami, M. Bull. Inst. Chem. Res., Kyoto Univ. **60**, 328-335 (1982).
246. Sugisaki, H. and Takanami, M. Nature New Biology **246**, 138-140 (1973).
247. Suri, B. and Bickle, T., unpublished observations.
248. Sussenbach, J.S., Monfoort, C.H., Schiphof, R. and Stobberingh, E.E. Nucleic Acids Res. **3**, 3193-3202 (1976).
249. Sussenbach, J.S., Steenbergh, P.H., Rost, J.A., van Leeuwen, W.J. and van Embden, J.D.A. Nucleic Acids Res. **5**, 1153-1163 (1978).
250. Sutcliffe, J.G. and Church, G.M. Nucleic Acids Res. **5**, 2313-2319 (1978).
251. Syddall, R.J., McGrath, K., Byron, J. and Stachow, C., unpublished observations.
252. Takahashi, H., unpublished observations.
253. Takahashi, H., Shimizu, M., Saito, H., Ikeda, Y. and Sugisaki, H. Gene **5**, 9-18 (1979).

254. Takanami, M. Methods in Mol. Biol. **7**, 113-133 (1974).
255. Timko, J., Horwitz, A.H., Zelinka, J. and Wilcox, G. J. Bacteriol. **145**, 873-877 (1981).
256. Tolstoshev, C.M. and Blakesley, R.W. Nucl. Acids Res. **10**, 1-17 (1982).
257. Tomassini, J., Roychoudhury, R., Wu, R. and Roberts, R.J. Nucleic Acids Res. **5**, 4055-4064 (1978).
258. Torheim, B., unpublished observations.
259. Trautner, T.A., unpublished observations.
260. Tu, C-P.D., Roychoudhury, R. and Wu, R. Biochem, Biophys, Res. Comm. **72**, 355-362 (1976).
261. van den Hondel, C.A.M.J.J., van Leen, R.W., van Arkel, G.A., Duyvesteyn, M. and deWaard, A., FEMS Microbiology Letters **16**, 7-12 (1983).
262. van Heuverswyn, H. and Fiers, W. Gene **9**, 195-203 (1980).
263. van Montagu, M., unpublished observations.
264. van Montagu, M., Sciaky, D., Myers, P.A. and Roberts, R.J., unpublished observations.
265. van Ormondt, H., Lautenberger, J.A., Linn, S. and deWaard, A. FEBS Letters **33**, 177-180 (1973).
266. Vanyushin, B.F. and Dobritsa, A.P. Biochim. Biophys. Acta **407**, 61-72 (1975).
267. Venegas, A., Vicuna, R., Alonso, A., Valdes, F. and Yudelevich, A. FEBS Letters **102**, 156-158 (1980).
268. Venetianer, P., unpublished observations.
269. Visentin, L.P., unpublished observations.
270. Visentin, L.P., Watson, R.J., Martin, S. and Zuker, M., unpublished observations.
271. Walter, F., Hartmann, M. and Roth, M. Abstracts of 12th FEBS Symposium, Dresden, (1978).
272. Wang, R.Y.-H., Shedlarski, J.G., Farber, M.B., Kuebbing, D. and Ehrlich, M. Biochim. Biophys. Acta **606**, 371-385 (1980).
273. Wani, A.A., Stephens, R.E., D'Ambrosio, S.M. and Hart, R.W. ASM Abstracts 1981. Abstract # 1778.
274. Watson, R., Zuker, M., Martin, S.M. and Visentin, L.P. FEBS Letters **118**, 47-50 (1980).
275. Watson, R.J., Schildkraut, I., Qiang, B.-Q., Martin, S.M. and Visentin, L.P. FEBS Letters **150**, 114-116 (1982).

- 276. Whitehead, P.R. and Brown, N.L. FEBS Letters **143**, 296-300 (1982).
- 277. Whitehead, P.R. and Brown, N.L., FEBS Letters **155**, 97-102 (1983).
- 278. Wilson, G.A. and Young, F.E. J. Mol. Biol. **97**, 123-125 (1975).
- 279. Wilson, G.A. and Young, F.E. Microbiology 1976. ed. D. Schlessinger, Amer. Soc. Microbiol., Washington pp. 350-357 (1976).
- 280. Wilson, G.A. and Young, F.E., unpublished observations.
- 281. Winkler, K. Diploma Dissertation (1979).
- 282. Winkler, K. and Rosch, A., unpublished observations.
- 283. Wu, R., King, C.T. and Jay, E. Gene **4**, 329-336 (1978).
- 284. Yoshimori, R.N. PhD Thesis (1971).
- 285. Zabeau, M., Greene, R., Myers, P.A. and Roberts, R.J., unpublished observations.
- 286. Zabeau, M. and Roberts, R.J., unpublished observations.
- 287. Zain, B.S. and Roberts, R.J. J. Mol. Biol. **115**, 249-255 (1977).