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Compilation of tRNA sequences

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INTRODUCTION

This compilation presents in a small space the tRNA sequences so far published in order to enable rapid orientation and comparison. The numbering of $tRNA^{Phe}$ from yeast is used as has been done earlier (1) but following the rules proposed by the participants of the Cold Spring Harbor Meeting on tRNA 1978 (2) (Fig. 1). This numbering allows comparisons with the three dimensional structure of $tRNA^{Phe}$, the only structure known from X-ray analysis. The secondary structure of tRNAs is indicated by specific underlining. In the primary structure a nucleoside followed by a nucleoside in brackets or a modification in brackets denotes that both types of nucleosides can occupy this position. Part of a sequence in brackets designates a piece of sequence not unambiguously analyzed. Rare nucleosides are named according to the IUPAC-IUB rules (for some more complicated rare nucleosides and their identification see Table 1); those with lengthy names are given with the prefix x and specified in the footnotes. Footnotes are numbered according to the coordinates of the corresponding nucleoside and are indicated in the sequence by an asterisk. The references are restricted to the citation of the latest publication in those cases where several papers deal with one sequence. For additional information the reader is referred either to the original literature or to other tRNA sequence compilations (3-7). Mutant tRNAs are dealt with in a separate compilation prepared by J. Celis (see below). The compilers would welcome any information by the readers regarding missing material or erroneous presentation. On the basis of this numbering system computer printed compilations of tRNA sequences in a linear form and in cloverleaf form are in preparation.

1. M. Sprinzl, F. Grüter, D.H. Gauss (1978) Nucleic Acids Research 5, r15-r27.

2. This rules are given with the compilation of tRNA sequences by D.H. Gauss, F. Grüter, M. Sprinzl in J. Abelson, P.R. Schimmel, D. Söll (Ed.) (1979) Cold Spring Harbor Symposia on Quantitative Biology, in press.

3. M.A. Sodd in G.D. Fasman (Ed.), CRC Handbook of Biochemistry and Molecular Biology, 3rd Edition, Nucleic Acids Vol. II, p. 423-456, The Chemical Rubber Company, Cleveland, 1976.

4. G. Dirheimer, J.P. Ebel, J. Bonnet, J. Gangloff, G. Keith, B. Krebs, B. Kuntzel, A. Roy, J. Weissenbach, C. Werner (1972) Biochimie 54, 127-144.

5. N.A. Sodd, B.P. Doctor (1974) Methods Enzymol. 29, 741-756.

6. B.G. Barrell, B.F.C. Clark, Handbook of Nucleic Acid Sequences, Joynson-Bruvvers Ltd. Oxford, 1974.

7. J. Barciszewski, A.J. Rafalski, Atlas of Transfer Ribonucleic Acids and Modified Nucleosides, Poznan, 1978, in press.

Table 1: Names of Some Rare Nucleosides and Citations Regarding their Identification

compare: M.Y. Feldman (1978) Progr.Biophys.Mol.Biol. 32, 83-102;
J.P. Goddard (1978) Progr.Biophys.Mol.Biol. 32, 233-308;
J.A. McCloskey, S. Nishimura (1977) Accounts Chem.Res. 10, 403-410.

o^5U	is uridine-5-oxyacetic acid.
mo^5U	is 5-methoxyuridine.
mcm^5U	is 5-methoxycarbonylmethyluridine, B. Kuntzel, J. Weissenbach, R.E. Wolff, T.D. Tumaitis-Kennedy, B.G. Lane, G. Dirheimer (1975) Biochimie 57, 61-70.
mcm^5s^2U	is 5-methoxycarbonylmethyl-2-thiouridine.
mam^5s^2U	is 5-N-methylaminomethyl-2-thiouridine.
i^6A	is N-6-(Δ^2-isopentenyl)adenosine.
ms^2i^6A	is N-6-(Δ^2-isopentenyl)2-methylthioadenosine, F. Harada, H.J. Gross, F. Kimura, S.H. Chang, S. Nishimura, U.L. RajBhandary (1968) Biochem.Biophys.Res.Commun 33, 299-306; Y. Yamada, S. Nishimura, H. Ishikura (1971) Biochim.Biophys.Acta 247, 170-174.
t^6A	is N-[9-(ß-D-ribofuranosyl)purin-6-ylcarbamoyl]threonine.
mt^6A	is N-[9-(ß-D-ribofuranosyl)purin-6-yl-N-methylcarbamoyl]threonine.
Q_{34}	is 7-(4,5-cisdihydroxy-1-cyclopenten-3-ylaminomethyl)-7-deazaguanosine, H. Casai, Z. Ohashi, F. Harada, S. Nishimura, N.J. Oppenheimer, P.F. Crain, J.G. Liehr, D.L. von Minden, J.A. McCloskey (1975) Biochem. 14, 4198-4208.
X	is 3-N-(3-amino-3-carboxypropyl)uridine, S. Nishimura, Y. Taya, Y. Kuchino, Z. Ohashi (1974) Biochem.Biophys.Res.Commun. 57, 702-708; Z. Ohashi, M. Maeda, J.A. McCloskey, S. Nishimura (1974) Biochem. 13, 2620-2625; S. Friedman, H.J. Li, K. Nakanishi, G. van Lear (1974) Biochem. 13, 2932-2937.
yW	is wybutosine, K. Nakanishi, N. Furutachi, M. Funamizu, D. Grunberger, I.B. Weinstein (1970) J.Amer.Chem.Soc. 92, 7617-7619.
O_2yW	is wybutoxosine, S.H. Blobstein, D. Grunberger, I.B. Weinstein, K. Nakanishi (1973) Biochem. 12, 188-193; A.M. Feinberg, K. Nakanishi, J. Barciszewski, A.J. Rafalski, H. Augustyniak, M. Wiewiorowski (1974) J.Amer.Chem.Soc. 96, 7797-7800.
N	is an unknown nucleoside.

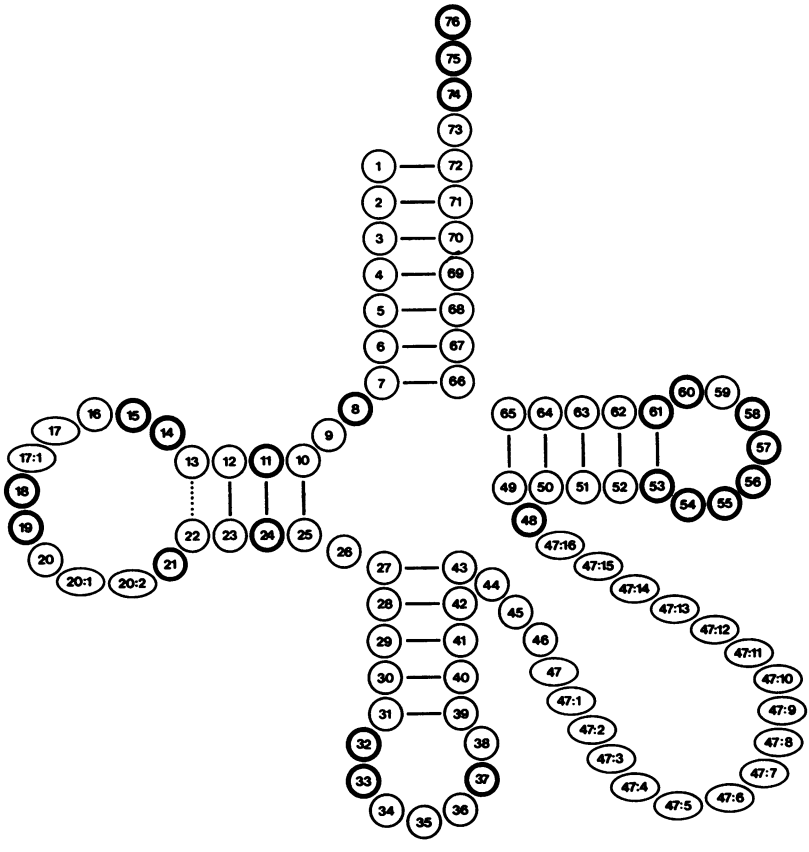
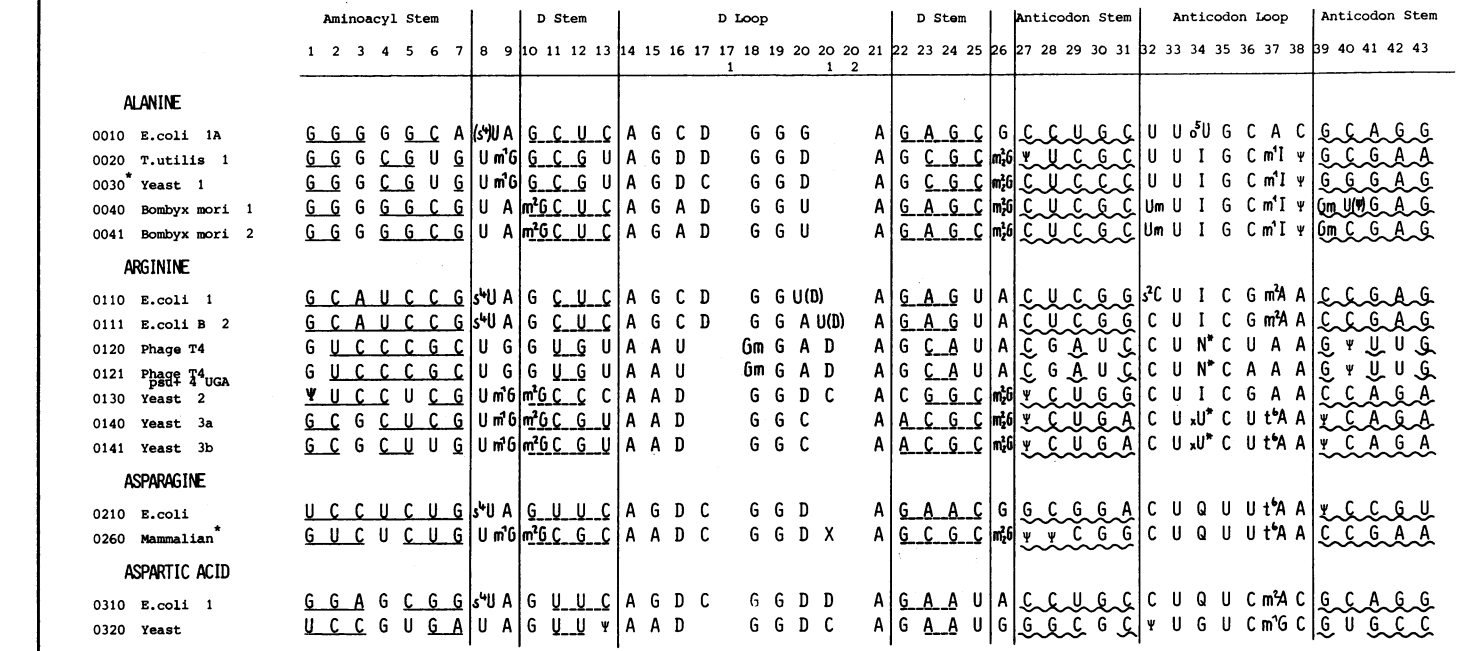


Figure 1: Numbering system of nucleotides in tRNAs according to the numbering of phenylalanine tRNA from yeast. Circles represent nucleotides which are always present; among these, the thick-edged circles denote invariant or semiinvariant nucleotides. Ovals represent nucleotides which are not present in each sequence: these are the nucleotides before the two constant GMP residues (18, 19) in the D loop, the nucleotides after these GMP residues, and the nucleotides in the variable loop which may be up to 17 nucleotides.

A nucleotide to be added at a given site is indicated by the number of the preceding nucleotide followed by a colon and a further number. Thus, e.g. 20:1 and 20:2 mean the first and second nucleotide after position 20. The absence of a nucleotide is indicated by the absence of a number, e.g. if no residue is found in position 17, the sequence then reads C16-G18. The numbering for the D loop, when one, two or three nucleotides are present each between 15 and 18 or between 19 and 21, is then 16 and 16, 17 and 16, 17, 17:1 or 20 and 20, 20:1 and 20, 20:1, 20:2, respectively. When the variable loop is five-membered the numbering is as in yeast phenylalanine tRNA 44, 45, 46, 47, 48. 47 is eliminated as the three dimensional structure of yeast phenylalanine tRNA suggests when the variable loop is four-membered. For large variable loops, numbers are added onto 47, e.g. for thirteen nucleotides 44, 45, 46, 47, 47:1, 47:2, 47:3, 47:4, 47:5, 47:6, 47:7, 47:8, 48.



0010 R.J.Williams,W.Nagel,B.Roe,B.Dudock (1974) Biochem.Biophys. Res.Commun. 60, 1215-1221.

0020 S.Takemura,K.Ogawa (1973) J.Biochem.74, 322-333.

0030 J.R.Penswick,R.Martin,G.Dirheimer (1975) FEBS-Lett. 50, 28-31.

0040 + 0041 K.U.Sprague,O.Hagenbüchle,M.C.Zuniga (1977) Cell 11, 561-570.

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0210 K.Ohashi,F.Harada,Z.Ohashi,S.Nishimura,T.S.Stewart,G.Vögeli, T.McCutchan,D.Söll (1976) Nucleic Acids Res. 3, 3369-3376.

0260 E.Y.Chen,B.A.Roe (1978) Biochem.Biophys.Res.Commun. 82, 235-246.

0310 F.Harada,K.Yamaizumi,S.Nishimura (1972) Biochem.Biophys.Res. Commun. 49, 1605-1609.

0320 J.Gangloff,G.Keith,J.P.Ebel,G.Dirheimer (1972) Biochim.Biophys. Acta 259, 210-222.

	Extra Arm																											TΨ Stem					TΨ Loop							TΨ Stem					Aminoacyl Stem								
	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	47 17	47 18	47 19	47 20	47 21	47 22	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
ALANINE																																																							
0010	A	G	m^7G	U																							C	U	G	C	G	G	T	Ψ	C	G	A	U	C	C	C	G	C	G	C	G	C	U	C	C	C	A	C	C	A
0020	A	G	G	D																							C	U	C	C	G	G	T	Ψ	C	G	m^1A	C	U	C	C	G	G	A	C	U	C	G	U	C	C	A	C	C	A
0030	A	G	G	D(U)																							C	U	C	C	G	G	T	Ψ	C	G	A	U	U	C	C	G	G	A	C	U	C	G	U	C	C	A	C	C	A
0040	A	G	m^7G	U																							A	m^5C	C	G	G	G	A	Ψ	C	G	m^1A	U	A	C	C	C	G	G	C	G	C	C	U	C	C	A	C	C	A
0041	A	G	m^7G	U																							A	m^5C	C	G	G	G	A	Ψ	C	G	m^1A	U	A	C	C	C	G	G	C	G	C	C	U	C	C	A	C	C	A
ARGININE																																																						
0110	C	G	m^7G	X																							C	G	G	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	C	C	C	G	G	A	U	G	C	A	C	C	A
0111	C	G	m^7G	X																							C	G	G	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	C	C	C	G	G	A	U	G	C	A	C	C	A
0120	C	G	G																								U	C	C	U	G	G	T	Ψ	C	G	A	U	C	C	C	A	G	G	G	G	C	G	G	G	G	A	U	A	C	C	A
0121	C	G	G																								U	C	C	U	G	G	T	Ψ	C	G	A	U	C	C	C	A	G	G	G	G	C	G	G	G	G	A	U	A	C	C	A
0130	A	G	A	D																							U	m^5C	C	A	G	G	T	Ψ	C	A	m^1A	G	U	C	C	U	G	G	C	G	G	G	G	A	A	G	C	C	A
0140	A	G	A	D																							U	A	U	G	G	G	T	Ψ	C	G	m^1A	C	C	C	C	C	A	U	C	G	A	G	U	G	C	G	C	C	A
0141	A	G	A	D																							U	A	U	G	G	G	T	Ψ	C	G	m^1A	C	C	C	C	C	A	U	C	G	A	G	U	G	C	U	C	C	A
ASPARAGINE																																																					
0210	A	U	m^7G	U																							C	A	C	U	G	G	T	Ψ	C	G	A	G	U	C	C	A	G	U	C	A	G	A	G	G	A	G	C	C	A
0260	A	G	m^7G	D																							U	G	G	U	G	G	N	Ψ	C	G	m^7A	G	C	C	C	A	C	C	C	A	G	G	G	A	C	G	C	C	A
ASPARTIC ACID																																																					
0310	G	G	m^7G	U																							C	G	C	G	G	G	T	Ψ	C	G	A	G	U	C	C	C	G	Ψ	C	C	G	U	U	C	C	G	C	C	A
0320	A	G	A																								U	m^5C	G	G	G	G	T	Ψ	C	A	A	U	U	C	C	C	C	G	U	C	G	G	G	G	A	G	C	C	A

0030/0 Compare R.W.Holley et al. (1965) Science 147, 1462-1465.

0120/34 N is a not identified derivative of uridine.

0121/34 N is a not identified derivative of uridine.

0140/34 xU is identified as mcm^5U.

0141/34 xU is identified as mcm^5U.

0260/0 Isolated from rat liver,human liver and human placenta.

		Aminoacyl Stem									D Stem				D Loop											D Stem					Anticodon Stem					Anticodon Loop							Anticodon Stem				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	17 1	18	19	20	20 1	20 2	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
CYSTEINE																																															
0410	E.coli	G	G	C	G	C	G	U	s^4U	A	A	C	A	A	A	G	C			G	G	D			D	A	U	G	U	A	G	C	G	G	A	Ψ	U	G	C	A	xA*	A	Ψ	C	C	G	U
0440	Yeast	G	C	U	C	G	U	A	U	G	G	C	G	C	A	G	D			G	G	D			A	G	C	G	C	A	G	C	A	G	A	Ψ	U	G	C	A	i^{6}A	A	Ψ	C	U	G	U
GLUTAMINE																																														
0510	E.coli K12 1	U	G	G	G	G	U	A	s^4U	C	G	C	C	A	A	G	C			Gm	G	D			A	A	G	G	C	A	C	C	G	G	U	Um	U	N*	U	G	m^{2}A	Ψ	A	C	C	G	G
0520	E.coli K12 2	U	G	G	G	G	U	A	s^4U	C	G	C	C	A	A	G	C			Gm	G	D			A	A	G	G	C	A	C	C	G	G	A	Um	U	C	U	G	m^{2}A	Ψ	Ψ	C	C	G	G
0530	Phage T4	U	G	G	G	A	A	U	s^4U	A	G	C	C	A	A	G	D	D		G	G	D			A	A	G	G	C	A	U	A	G	C	A	C	U	N*	U	G	m^{2}A	C	Ψ	G	C	U	A
0531	Phage T4 psu+2 oc	U	G	G	G	A	A	U	s^4U	A	G	C	C	A	A	G	D	D		G	G	D			A	A	G	G	C	A	U	A	G	C	A	C	U	N*	U	A	m^{2}A	C	Ψ	G	C	U	A
0532	C34 psu+2 am	U	G	G	G	A	A	U	s^4U	A	G	C	C	A	A	G	D	D		G	G	D			A	A	G	G	C	A	U	A	G	C	A	C	U	C	U	A	m^{2}A	C	Ψ	G	C	U	A
0540	Phage T4 (from precurs.)	U	G	G	G	A	A	U	s^4U	A	G	C	C	C	A	A	G	D	D	G	G	D	A		A	G	G	G	C	A	U	A	G	C	A	C	U	N*	U	G	m^{2}A	C	Ψ	G	C	U	A
GLUTAMIC ACID																																														
0610	E.coli B 1	G	U	C	C	C	C	U	U	C	G	U	C	Ψ	A	G	A			G	G	C	C	C	A	G	G	A	C	A	C	C	G	C	C	C	U	xU*	U	C	m^{2}A	C	G	G	C	G	G
0620	E.coli 2	G	U	C	C	C	C	U	U	C	G	U	C	Ψ	A	G	A			G	G	C	C	C	A	G	G	A	C	A	C	C	G	C	C	C	U	xU*	U	C	m^{2}A	C	G	G	C	G	G
0630	Yeast 3	U	C	C	G	A	U	A	U	A	G	U	G	Ψ	A	A	C			G	G	C	D		A	U	C	A	C	A	Ψ	C	A	C	G	C	U	xU*	U	C	A	C	C	G	U	G	G

0410 G.P.Mazzara,W.H.McClain (1977) J.Mol.Biol. 117,1061-1079.
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0532 M.M.Comer,K.Foss,W.H.McClain (1975) J.Mol.Biol. 99, 283-293.
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0630 T.Kobayashi,T.Irie,M.Yoshida,K.Takeishi,T.Ukita (1974) Biochim. Biophys.Acta 366, 168-181.

	Extra Arm																							T Ψ Stem					T Ψ Loop							T Ψ Stem					Aminoacyl Stem								
	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
CYSTEINE																																																	
0410	C	U	A																		G	U	C	C	G	G	T	Ψ	C	G	A	C	U	C	C	G	G	A	A	C	G	C	G	C	C	U	C	C	A
0440	U	G	m^7G	D																	m^5C	C	U	U	A	G	T	Ψ	C	G	m^1A	U	C	C	U	G	A	G	U	G	C	G	A	G	C	U	C	C	A
GLUTAMINE																																																	
0510	C	A	U	U																	C	C	C	U	G	G	T	Ψ	C	G	A	A	U	C	C	A	G	G	U	A	C	C	C	C	A	G	C	C	A
0520	C	A	U	U																	C	C	G	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	C	G	U	A	C	C	C	C	A	G	C	C	A
0530	G	A	U	G																	C	A	A	A	G	G	T	Ψ	C	G	A	G	U	C	C	U	U	U	A	U	U	C	C	C	A	G	C	C	A
0531	G	A	U	G																	C	A	A	A	G	G	T	Ψ	C	G	A	G	U	C	C	U	U	U	A	U	U	C	C	C	A	G	C	C	A
0532	G	A	U	G																	C	A	A	A	G	G	T	Ψ	C	G	A	G	U	C	C	U	U	U	A	U	U	C	C	C	A	G	C	C	A
0540	G	A	U	G																	C	A	A	A	G	G	T	Ψ	C	G	A	G	U	C	C	U	U	U	A	U	U	C	C	C	A	G	C	C	A
GLUTAMIC ACID																																																
0610	U	A	A																		C	A	G	G	G	G	T	Ψ	C	G	A	A	U	C	C	C	C	U	G	G	G	G	G	A	C	G	C	C	A
0620	U	A	A																		C	A	G	G	G	G	T	Ψ	C	G	A	A	U	C	C	C	C	U	A	G	G	G	G	A	C	G	C	C	A
0630	A	G	A																		C	m^5C	G	G	G	G	T	Ψ	C	G	A	C	U	C	C	C	C	G	U	A	U	C	G	G	A	G	C	C	A

0410/37 xA is ms^2i^6A.

0510/34 N is likely a derivative of 2-thiouridine.

0530/34 N is an unknown derivative of uridine.

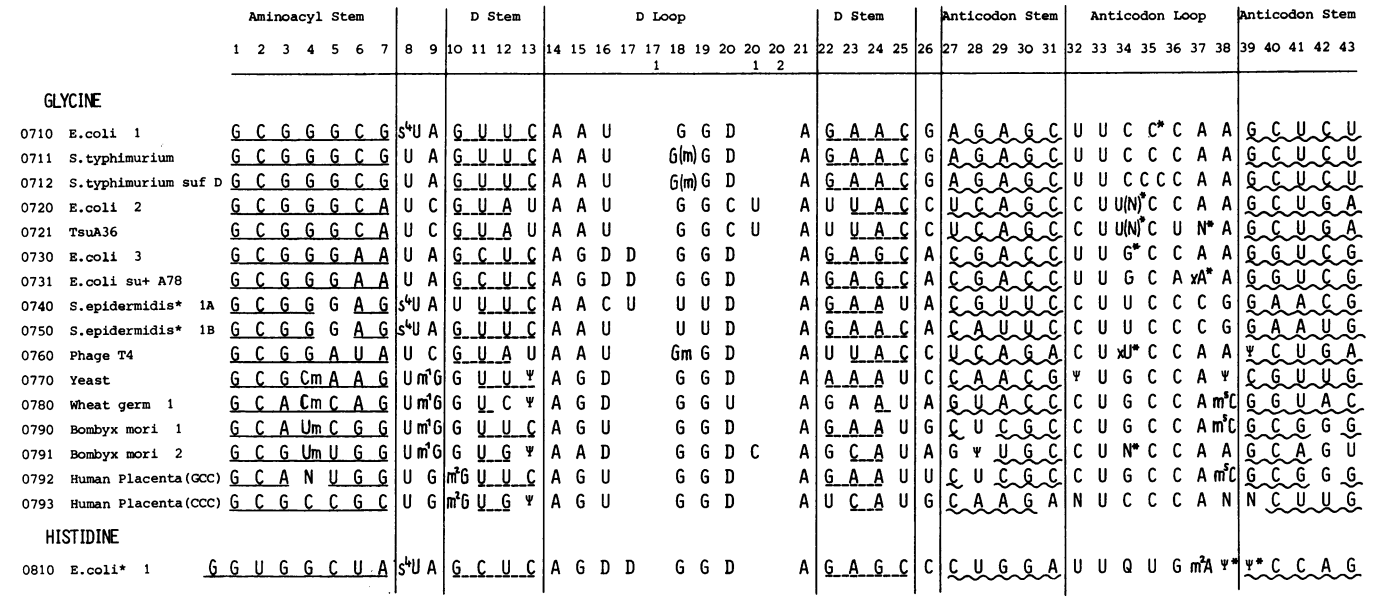
0531/34 N is an unknown derivative of uridine.

0540/34 N is an unknown derivative of uridine.

0610/34 xU is mam^5s^2U.

0620/34 xU is mam^5s^2U.

0630/34 xU is mcm^5s^2U.



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0792 + 0793 R.C.Gupta,B.A.Roe,K.Randerath (1978) Cold Spring Harbor Meeting on tRNA,Abstracts,p.5.

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	Extra Arm																							TΨ Stem					TΨ Loop							TΨ Stem					Aminoacyl Stem								
	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	47 17	47 18	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
GLYCINE																																																		
0710	A	U	A																				C	G	A	G	G	G	T	Ψ	C	G	A	U	U	C	C	C	U	U	C	G	C	C	C	G	C	U	C	C	A
0711	A	U	A																				C	G	A	G	G	G	T	Ψ	C	G	A	U	U	C	C	C	U	U	C	G	C	C	C	G	C	U	C	C	A
0712	A	U	A																				C	G	A	G	G	G	T	Ψ	C	G	A	U	U	C	C	C	U	U	C	G	C	C	C	G	C	U	C	C	A
0720	U	G	A																				U	G	C	G	G	G	T	Ψ	C	G	A	U	U	C	C	C	G	C	U	G	C	C	C	G	C	U	C	C	A
0721	U	G	A																				U	G	C	G	G	G	T	Ψ	C	G	A	U	U	C	C	C	G	C	U	G	C	C	C	G	C	U	C	C	A
0730	G	G	m^{3}G	U																			C	G	C	G	A	G	T	Ψ	C	G	A	G	U	C	U	C	G	U	U	U	C	C	C	G	C	U	C	C	A
0731	G	G	m^{3}G	U																			C	G	C	G	A	G	T	Ψ	C	G	A	G	U	C	U	C	G	U	U	U	C	C	C	G	C	U	C	C	A
0740	A	G	A																				U	A	U	A	G	G	U	G	C	A	A	A	U	C	C	U	A	U	C	U	U	C	C	G	C	U	C	C	A
0750	A	G	G																				U	A	U	A	G	G	U	G	C	A	A	G	U	C	C	U	A	U	C	U	U	C	C	G	C	U	C	C	A
0760	U	G	A																				U	G	U	G	A	G	T	Ψ	C	G	A	U	U	C	U	C	A	U	U	A	U	C	C	G	C	U	C	C	A
0770	G	G																					C	m^{5}C	C	C	G	G	T	Ψ	C	G	A	U	U	C	C	G	G	G	C	U	U	G	C	G	C	A	C	C	A
0780	A	G	A																				m^{5}C	m^{5}C	m^{5}C	G	G	G	U	Ψ	C	G	m^{1}A	U	U	C	C	C	G	G	C	U	G	G	U	G	C	A	C	C	A
0790	C	G	G																				m^{5}C	m^{5}C	m^{5}C	G	G	G	T	Ψ	C	G	m^{1}A	U	U	C	C	C	G	G	C	C	G	A	U	G	C	A	C	C	A
0791	U	G	A																				U	m^{5}C	m^{5}C	G	G	G	T	Ψ	C	G	m^{1}A	U	U	C	C	C	G	G	C	C	A	A	C	G	C	A	C	C	A
0792	A	G	G																				m^{5}C	m^{5}C	m^{5}C	G	G	G	T	Ψ	C	G	m^{1}A	U	U	C	C	C	G	G	C	C	A	A	U	G	C	A	C	C	A
0793	C	G	A																				C	m^{5}C	m^{5}C	G	G	G	T	Ψ	C	G	m^{1}A	U	U	C	C	C	G	G	G	C	G	G	C	G	C	A	C	C	A
HISTIDINE																																																	
0810	U	U	m^{1}G	U																			C	G	U	G	G	G	T	Ψ	C	G	A	A	U	C	C	C	A	U	U	A	G	C	C	A	C	C	C	A

0710/35 Mutation C-35→U-35;C.W.Hill,G.Combriato,W.Dolph(1974) J.Bacteriol.117, 351-359.

0720/34 N is an unidentified derivative of uridine.

0721/34 N is an unidentified derivative of uridine.

0721/37 N is probably a derivative of adenosine.

0730/34 Mutation:E.coli ins has G-34→U-34.

0731/37 xA is ms^{2}i^{6}A.

0740/0 Staphylococcus epidermidis Texas 26.

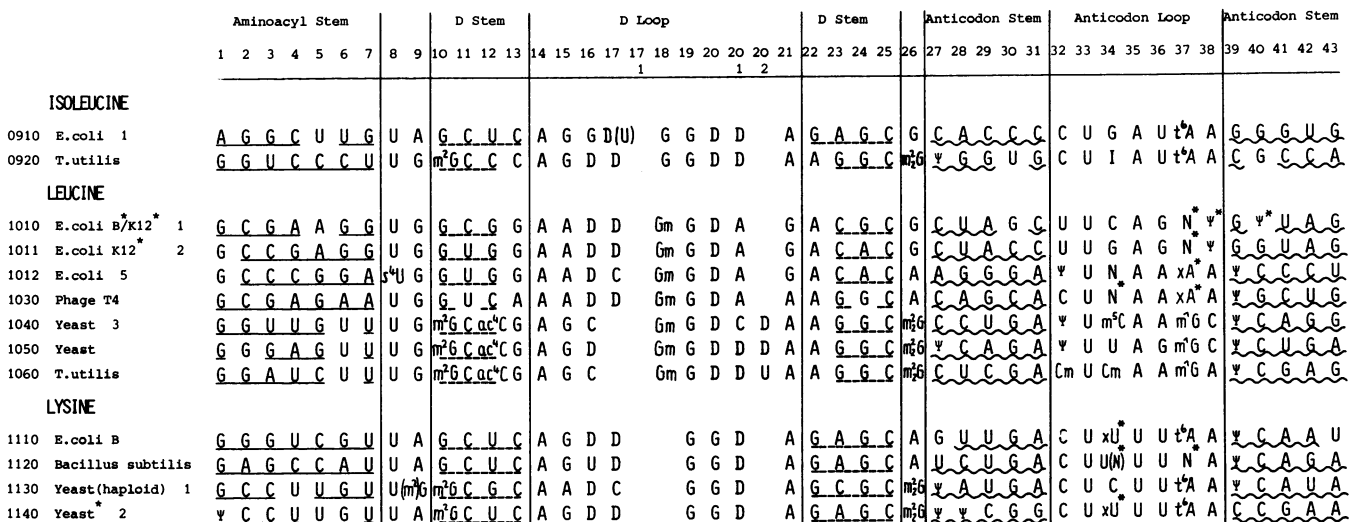
0750/0 Staphylococcus epidermidis Texas 26.

0760/34 xU is probably related to mam^{5}s^{2}U.

0791/34 N contains 2 unknown modified nucleosides.They are probably derivatives of uridine.

0810/0 Identical with Salmonella typhimurium.

0810/38 + 0810/39 HisT mutation Ψ -38→U-38, Ψ-39→U-39; C.E.Singer,G.R.Smith, R.Cortese,B.N.Ames(1972) Nature New Biology 238, 72-74.



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	Extra Arm																							T Ψ Stem					T Ψ Loop							T Ψ Stem					Aminoacyl Stem								
	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	47 17	47 18	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
ISOLEUCINE																																																		
0910	A	G	m^7G	X*																			C	G	G	U	G	G	T	Ψ	C	A	A	G	U	C	C	A	C	Ψ	C	A	G	G	C	C	U	A	C	C	A
0920	A	G	A	D																			m^5C	A	G	C	A	G	T	Ψ	C	G	m^1A	U	C	C	U	G	C	U	A	G	G	G	A	C	C	A	C	C	A
LEUCINE																																																		
1010	U	G	U	C	C	U	U	A	C	G	G	A	C	G									U	G	G	G	G	G	T	Ψ	C	A	A	G	U	C	C	C	C	C	C	C	U	C	G	C	A	C	C	A
1011	U	G	C	C	C	A	A	U	A	G	G	G	C	U									U	A	C	G	G	G	T	Ψ	C	A	A	G	U	C	C	C	G	U	C	C	U	C	G	G	U	A	C	C	A
1012	C	G	G	C	G	U	U	C	G	C	G	C	U	G									U	G	C	G	G	G	T	Ψ	C	A	A	G	U	C	C	C	G	C	U	C	C	G	G	G	U	A	C	C	A
1030	C	G	G	A	A	U	G	A	U	U	U	C	C	U									U	G	U	G	G	G	T	Ψ	C	G	A	G	U	C	C	C	A	C	U	U	C	U	C	G	C	A	C	C	A
1040	U	A	U	C	G	U	A	A	G	A	U	G											m^5C	A	A	G	A	G	T	Ψ	C	G	A	A	U	C	U	C	U	U	A	G	C	A	A	C	C	A	C	C	A
1050	U	A	U	C	U	U	C	G	G	A	U	G											m^5C	A	A	G	G	G	T	Ψ	C	G	m^1A	A	U	C	C	C	U	U	A	G	C	U	C	U	C	A	C	C	A
1060	U	A	U	C	G	U	A	A	G	A	U	G											m^5C	A	U	G	A	G	T	Ψ	C	G	m^1A	A	U	C	U	C	A	U	A	G	G	A	U	C	C	A	C	C	A
LYSINE																																																		
1110	U	G	m^7G	X																			C	G	C	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	G	C	A	C	G	A	C	C	C	A	C	C	A
1120	G	G	m^7G	U																			C	G	A	A	G	G	T	Ψ	C	G	A	G	U	C	C	U	U	C	A	U	G	G	C	U	C	A	C	C	A
1130	A	G	m^7G	U																			U	A	G	G	G	G	T	Ψ	C	G	m^1A	G	C	C	C	C	C	U	A	C	A	G	G	G	C	U	C	A	C	C	A
1140	A	U	m^7G	D(U)																			m^5C	A	G	G	G	G	T	Ψ	C	G	m^1A	G	C	C	C	C	C	U	A	Ψ	G	A	G	G	A	G	C	C	A

0910/47 Probably X, 3N-(3-amino-3-carboxypropyl)uridine, S.Friedman, H.J.Li, K.Nakanishi, G.van Lear (1974) Biochemistry 13, 2932-2937.

1010/0 Identical with Salmonella typhimurium LT2 $tRNA_1^{Leu}$.

1010/38 His T mutanat of Salmonella typhimurium $tRNA_1^{Leu}$ has Ψ-38→U-38 and
1010/40 Ψ-40→U-40, H.S.Allaudeen, S.K.Yang, D.Söll (1972) FEBS-Lett. 28, 205-208.

1010/0 For numbering of E.coli leucine tRNAs see R.E.Hurd, G.T.Robillard,
1011/0 B.A.Reid (1977) Biochemistry 16, 2095-2100.

1010/37 N is an unknown derivative of guanosine.

1011/37 N is an unknown derivative of guanosine.

1012/37 xA is ms^2i^6A.

1030/34 N is an unknown derivative of uridine.

1030/37 xA is ms^2i^6A.

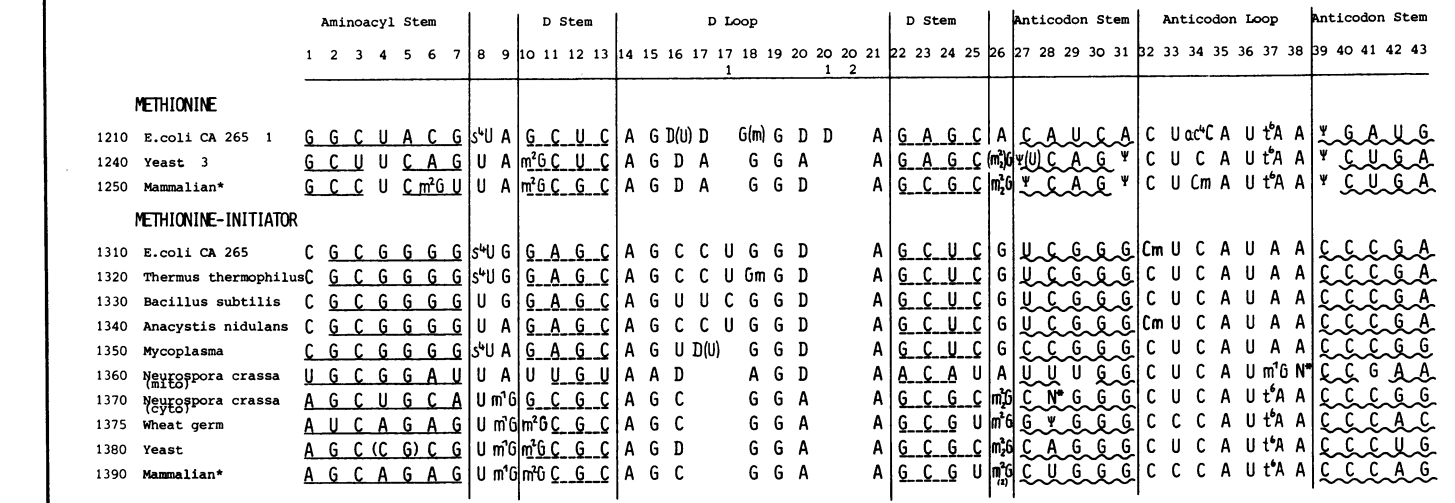
1110/34 xU is mam^5s^2U.

1120/34 U is partially replaced by N, which is probably a derivative of 2-thiouridine.

1120/37 N is an unknown derivative of guanosine.

1140/0 Is identical with Saccharomyces cerivisiae haploid 2, C.J.Smith, H.-S.Teh, A.N.Ley, P.D'Obrenan (1973) J.Biol.Chem. 248, 4475.4485.

1140/34 xU is mcm^5s^2U.



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	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
	Extra Arm																					TΨ Stem					TΨ Loop							TΨ Stem					Aminoacyl Stem										
METHIONINE																																																	
1210	G	G	m^7G	X																	C	A	C	A	G	G	T	ψ	C	G	A	A	U	C	C	C	G	U	C	G	U	A	G	C	C	A	C	C	A
1240	A	G	m^7G	D(U)																	m^5C	G	A	G	A	G	T	ψ	C	G	m^1A	A	C	C	U	C	U	C	C	U	G	G	A	G	C	A	C	C	A
1250	A	G	m^7G	D																	m^5C	G	U	G	A	G	T	ψ	C	G	m^1A	U	C	C	U	C	A	C	A	C	G	G	G	G	C	A	C	C	A
METHIONINE-INITIATOR																																																	
1310	A	G	m^7G^*	U																	C	G	U	C	G	G	T	ψ	C	A	A	A	U	C	C	G	G	C	C	C	C	C	G	C	A	A	C	C	A
1320	A	G	m^7G	U																	C	G	C	G	G	G	s^2T	ψ	C	A	m^1A	A	U	C	C	C	G	C	C	C	C	C	G	C	A	A	C	C	A
1330	A	G	G	U																	C	G	C	A	G	G	T	ψ	C	A	A	A	U	C	C	U	G	C	C	C	C	C	G	C	A	A	C	C	A
1340	A	G	m^7G	U																	C	A	G	A	G	G	T	ψ	C	A	A	A	U	C	C	U	C	U	C	C	C	C	G	C	C	A	C	C	A
1350	A	G	G	C																	C	G	C	A	G	G	U	ψ	C	G	A	G	U	C	C	U	G	C	C	C	C	C	G	C	A	A	C	C	A
1360	U	G	A																		C	A	U	A	G	G	U	G	C	A	A	A	U	C	C	U	G	U	A	U	C	C	G	C	A	U	C	C	A
1370	A	G	m^7G	U(D)																	C	A	C	U	C	G	A	U	C	G	m^1A	A	A	C	G	A	N*	U	U	G	C	A	G	C	U	A	C	C	A
1375	A	G	m^7G	D																	m^5C	m^5C	C	A	G	G	A	ψ	C	G	m^1A	A	A	C	C	U	G	G*	C	U	C	U	G	A	U	A	C	C	A
1380	A	U	m^7G	D																	m^5C	m^5C	U	C	G	G	A	U	C	G	m^1A	A	A	C	C	G	N*	N*	C	G	(C	G)	G	C	U	A	C	C	A
1390	A	G	m^7G	D																	m^5C	G	A	U	G	G	A	U	C	G	m^1A	A	A	C	C	A	U	C	C	U	C	U	G	C	U	A	C	C	A

1250/0 Mouse myeloma and rabbit liver.

1310/46 m^7G-46→A-46 in the minor species of $tRNA^{fMet}$ from E.coli, S.K.Dube, K.A.Marcker,B.F.C.Clark,S.Cory (1968) Nature 218, 231-233; B.Z.Egan,J.F.Weiss,A.D.Kelmers (1973) Biochem.Biophys.Res.Commun. 55, 320-327.

1360/38 N is most probably pseudouridine.

1370/28 N is an unidentified derivative of pyrimidine.

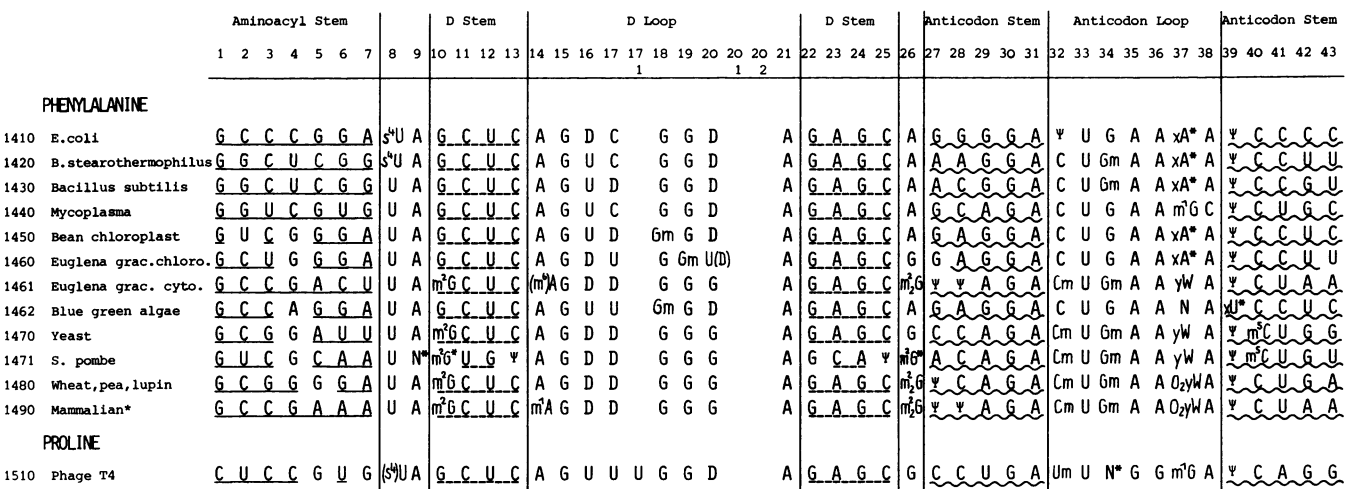
1370/64 N is an unidentified derivative of guanosine.

1375/65 Is probably a modified derivative of guanosine.

1380/64 N is an unidentified derivative of adenosine.

1380/65 N is an unidentified derivative of guanosine.

1390/0 Rabbit liver,sheep mammary glands,salmon testes,salmon liver,human placenta,mouse myeloma cells,oocytes and somatic cells of Xenopus laevis.



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	Extra Arm																								TΨ Stem					TΨ Loop							TΨ Stem					Aminoacyl Stem								
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PHENYLALANINE																																																			
1410	G	U	m^7G	X																		C	C	U	U	G	G	T	Ψ	C	G	A	U	U	C	C	G	A	G	U	C	C	G	G	G	C	A	C	C	A
1420	G	U	m^7G	U																		C	G	G	C	G	G	T	Ψ	C	G	A	U	U	C	C	G	U	C	C	C	G	A	G	C	C	A	C	C	A
1430	G	U	m^7G	U																		C	G	G	C	G	G	T	Ψ	C	G	A	U	U	C	C	G	U	C	C	C	G	A	G	C	C	A	C	C	A
1440	G	U	m^7G	U																		C	G	G	C	G	G	U	Ψ	C	A	A	U	U	C	C	G	U	C	C	A	C	G	A	C	C	A	C	C	A
1450	C	U	m^7G	X																		C	A	C	C	A	G	T	Ψ	C	A	A	A	U	C	U	G	G	U	U	C	C	U	G	G	C	A	C	C	A
1460	G	U	m^7G	X																		C	A	C	C	A	G	T	Ψ	C	A	A	A	U	C	U	G	G	U	U	C	C	U	A	G	C	A	C	C	A
1461	A	G	m^7G	xU*																		C	C	C	U	G	G	T	Ψ	C	G	m^1A	U	C	C	C	G	G	G	A	G	Ψ	C	G	G	C	A	C	C	A
1462	G	U	m^7G	U																		m^5C	G	G	C	G	G	T	Ψ	C	A	A	U	U	C	C	G	C	C	U	C	C	C	G	G	C	A	C	C	A
1470	A	G	m^7G	U																		C	m^5C	U	G	U	G	T	Ψ	C	G	m^1A	U	C	C	A	C	A	G	A	A	U	U	C	G	C	A	C	C	A
1471	U	G	m^7G	xU*																		C	A	U	C	G	G	T	Ψ	C	G	A	U	C	C	C	G	G	U	U	U	G	U	G	A	C	A	C	C	A
1480	A	G	m^2G	D																		C	G*	C	G	U	G	T	Ψ	C	G	m^1A	U	C	C	A	C	G	C*	U	C	A	C	C	G	C	A	C	C	A
1490	A	G	m^7G	(D)																		C	m^5C	C	U	G	G	T(U)*	Ψ	C	G	m^1A	U	C	C	C	G	G	G	U	U	U	C	G	G	C	A	C	C	A
PROLINE																																																			
1510	A	G	m^7G	U																		C	C	A	A	G	G	T	Ψ	C	A	A	A	U	C	C	U	U	G	U	A	U	G	G	A	G	A	C	C	A

1410/37 xA is ms^2i^6A.

1420/37 xA is ms^2i^6A.

1430/37 xA is ms^2i^6A.

1450/37 xA is ms^2i^6A.

1460/37 xA is ms^2i^6A.

1461/47 xU is probably a derivative of uridine.

1462/39 xU is probably a derivative of uridine.

1471/9 N is an unidentified derivative of guanosine.

1471/10 Is probably m^2G.

1471/26 Is probably m^2G.

1471/47 xU is probably a derivative of uridine.

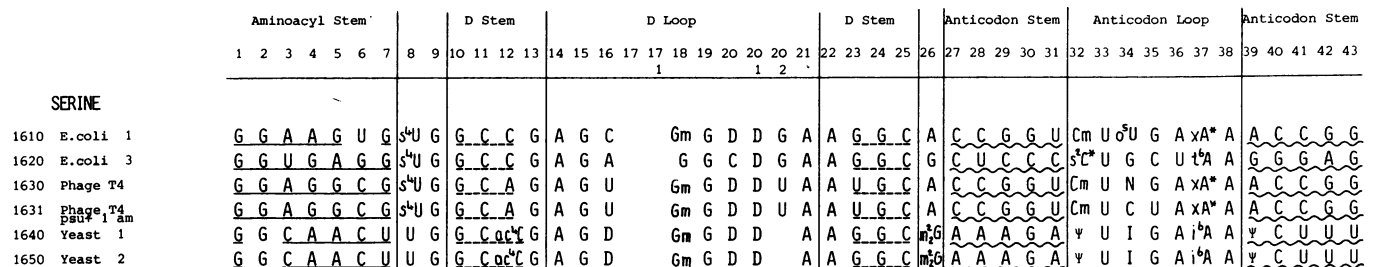
1480/49 The Lupinus luteus sequence has mainly adenosine.

1480/65 The Lupinus luteus sequence has mainly uridine.

1490/0 Rabbit liver, calf liver, bovine liver and human placenta.

1490/54 Content of T is different for different species.

1510/34 N is an unidentified derivative of uridine.



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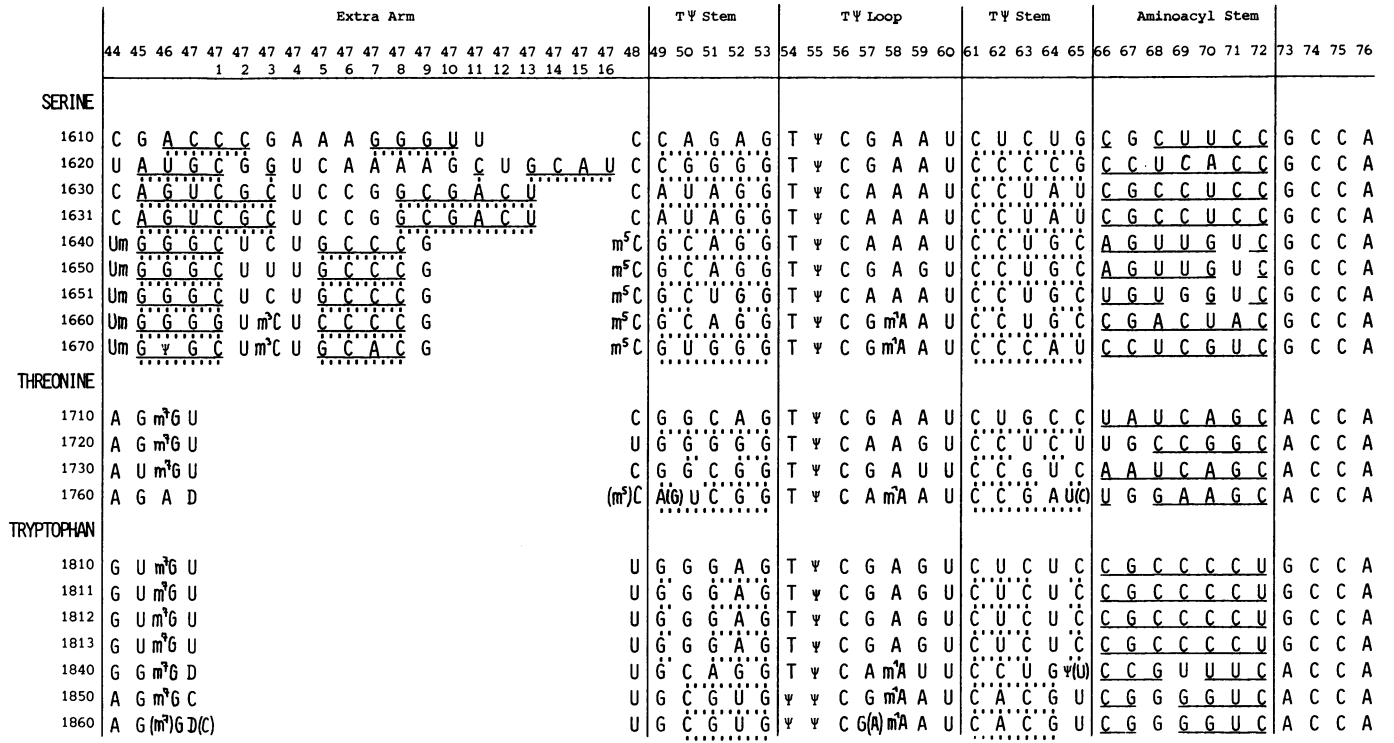


1610/37 xA is ms^2i^6A.

1620/32 In the position 32 is most probably 2-thiocytidine.

1630/37 xA is ms^2i^6A.

1631/37 xA is ms^2i^6A.

1651/0 A minor species has G-28,C-42 and U(m)-44.

1651/35 Suppressor sup-R11 has U-35.

1730/34 N is an unknown derivative of uridine.

1730/37 N is an unknown derivative of adenosine.

1810/8 The s^4U-8—C-13 cross link was identified.

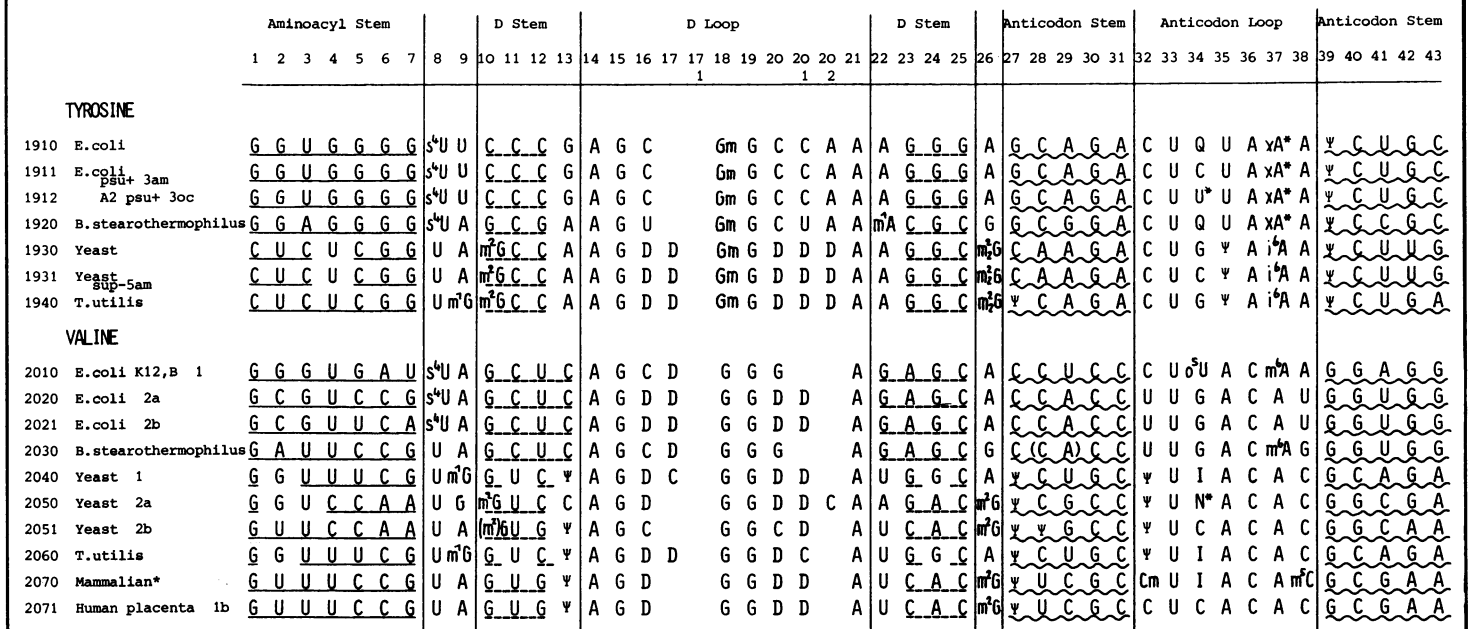
1810/37 xA is ms^2i^6A.

1811/37 xA is ms^2i^6A.

1812/37 xA is ms^2i^6A.

1813/37 xA is ms^2i^6A.

1850/0 The sequence was determined on primer RNA for initiation of in vitro Rous-Sarcoma virus DNA synthesis;tRNA-Trp from chicken cells has an identical composition;L.C. Waters,W.-K.Yang(1975)J.Biol.Chem.250, 6627-6629.



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	Extra Arm																							T ψ Stem					T ψ Loop							T ψ Stem					Aminoacyl Stem								
	44	45	46	47	47 1	47 2	47 3	47 4	47 5	47 6	47 7	47 8	47 9	47 10	47 11	47 12	47 13	47 14	47 15	47 16	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
TYROSINE																																																		
1910	C	G	U	C	A	U	(C)	C	(A)	G	A	C	U	U								C	G	A	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	U	C	C	C	C	C	A	C	C	A
1911	C	G	U	C	A	U	C			G	A	C	U	U								C	G	A	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	U	C	C	C	C	C	A	C	C	A
1912	C	G	U	C	A	U	C			G	A	C	U	U								C	G	A	A	G	G	T	Ψ	C	G	A	A	U	C	C	U	U	C	C	C	C	C	A	C	C	A
1920	U	C	C	C	U	U	U			G	G	G	U	U								C	G	G	C	G	G	T	Ψ	C	G	A	A	U	C	C	G	U	C	C	C	C	C	U	C	C	A
1930	A	G	A	D																		m^5C	G	G	G	C	G	T	Ψ	C	G	m^1A	C	U	C	G	C	C	C	C	C	G	G	G	A	G	A	C	C	A
1931	A	G	A	D																		m^5C	G	G	G	C	G	T	Ψ	C	G	m^1A	C	U	C	G	C	C	C	C	C	G	G	G	A	G	A	C	C	A
1940	A	C	A	D																		m^5C	G	G	G	C	G	T	Ψ	C	G	m^1A	A	U	C	G	C	C	C	C	C	G	A	G	A	G	A	C	C	A
VALINE																																																		
2010	G	G	m^7G	U																		C	G	G	C	G	G	T	Ψ	C	G	A	U	C	C	C	G	U	C	A	U	C	A	C	C	C	A	C	C	A
2020	G	G	m^7G	X																		C	G	G	U	G	G	T	Ψ	C	G	A	G	U	C	C	A	C	U	C	G	G	A	C	G	C	A	C	C	A
2021	G	G	m^7G	X																		C	G	U	U	G	G	T	Ψ	C	G	A	G	U	C	C	A	A	U	U	G	A	A	C	G	C	A	C	C	A
2030	A	G	m^7G	U																		C	G	C	U	G	G	T	Ψ	C	G	A	G	C	C	C	A	G	U	C	G	G	A	A	U	C	A	C	C	A
2040	A	C	m^7G	D																		C	m^5C	C	C	A	G	T	Ψ	C	G	m^1A	U	C	C	U	G	G	G	C	G	A	A	A	U	C	A	C	C	A
2050	A	G	A	D																		C	m^5C	C	G	A	G	T	Ψ	C	G	m^1A	A	C	C	U	C	G	G	U	U	G	G	A	U	C	A	C	C	A
2051	A	G	m^7G	D																		C	m^5C	C	G	A	G	T	Ψ	C	G	m^1A	U	C	C	U	C	G	G	U	U	G	G	A	U	C	A	C	C	A
2060	A	C																				m^5C	C	C	C	A	G	T	Ψ	C	G	m^1A	U	C	C	U	G	G	G	C	G	A	A	A	U	C	A	C	C	A
2070	A	G	m^7G	D																		m^5C	m^5C	C	C	G	G	U*	Ψ	C	G	m^1A	A	A¶	C	C	G	G	G	C	G	G	A	A	A	C	A	C	C	A
2071	A	G	m^9G	D																		m^5C	m^5C	C	C	G	G	U	Ψ	C	G	m^1A	A	A	C	C	G	G	G	C	G	G	A	A	A	C	A	C	C	A

1910/37 xA is ms^2i^6A

1911/37 xA is ms^2i^6A.

1912/34 Uridine may be modified; S.Altman(1976) Nucleic Acids Res. 3, 441-448.

1912/37 xA is ms^2i^6A.

1920/37 xA is ms^2i^6A.

2050/34 N is an unknown derivative of uridine.

2070/0 Mouse myeloma,rabbit liver and human placenta 1a, in the latter case C-32 and C-38 are unmodified.

2070/54 The U-54 A-60 base pair was detected by P.Jank,
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