Proc. Natl. Acad. Sci. USA
Vol. 74, No. 6, pp. 2222–2230, June 1977
Biochemistry

Nomenclature of phosphorus-containing compounds of biochemical importance (Recommendations 1976)*

IUPAC–IUB COMMISSION ON BIOCHEMICAL NOMENCLATURE†

The IUPAC Commissions on the Nomenclature of Inorganic and of Organic Chemistry (CNIC and CNOC) have recently provided, in the "D-Rules" (1), recommendations for naming a large number of organic compounds containing phosphorus. Many such compounds are extremely important in biochemistry and hence in nearly all branches of biology and medicine. Most of the biochemically important ones are esters and/or anhydrides of various phosphorus-containing acids with complex organic alcohols and organic acids. Strict application of the "D Rules" (1) to such compounds would result, in many cases, in rather complicated names, and these would be inconvenient for most biochemists and biologists to use.

However, other systems of nomenclature, in use in the biochemical literature, are available (2–5). It is the purpose of this document to define and recommend certain of these for naming organic phosphorus-containing compounds in biochemical, biological, and medical publications.

A general summary and explanation of the principles involved in the nomenclature of biochemically important organic phosphorus compounds is given below. Representative compounds and their recommended names, together with those derived from more systematic nomenclature (4, 6, 7), including names formed according to the "D Rules" (1) where appropriate, are listed in the tables.

1. **Phosphoric esters,** $RO\text{-}PO(OH)_2$, are named as *O*-substituted phosphoric acids or as substituted alcohols (Table 1). Thus, choline *O*-(dihydrogen phosphate) and *O*-phosphonocholine are both appropriate names. The latter may be contracted to phosphocholine, but not changed to phosphorylcholine; "phosphoryl" is defined (ref. 1, Rule 5.66) as OP< and requires, if used, the naming of all three groups attached to the phosphorus atom. However, "phosphoryl" is retained in derived terms such as the names of enzymes (e.g., phosphorylase) or of processes (e.g., phosphorylation).

Comment. The form *O*-phosphono-R stems from two considerations, (*i*) the definition (ref. 1, Rule 5.51) of phosphonic acid as $HPO(OH)_2$, and (*ii*) the principle in organic nomenclature of substitution of another atom or group for a hydrogen atom of a parent molecule, which, in this case, involves the replacement of the H of an OH group by $-P(O)(OH)_2$, the phosphono group (ref. 1, Rule 5.52).

2. **Phosphate** may be used for "(dihydrogen phosphate)," "(disodium phosphate)," etc., (*a*) if the nature of the counterions is not known or is of no importance in the context, or (*b*) if a mixture of ionic forms (free acid and/or monoanion and/or dianion) is in question. Thus, in most biochemical or biological systems, where the pH is around 7, "glucose phosphate" may be used in place of "glucose dihydrogen phosphate," the proper names for the protonated form.

Comments. (*i*) Although glucose phosphate is an ester, the term "phosphate ester" should not be used: "phosphoric ester" is the appropriate generic term. (*ii*) When "phosphoric" is followed by a generic term (e.g., ester, amide, group), the word "acid" need not intervene. Hence, "phosphoric ester" is complete and sufficient, and the residue transferred to glucose to form *O*-phosphonoglucose (see Section 1 above) is a "phosphoric residue." (*iii*) To distinguish choline phosphate (ester) from choline phosphate (salt), the former could be written "choline *O*-phosphate." However, "phosphocholine" is unambiguous. (For *N*-phosphono compounds, see Section 6.)

3. **Phosphoric anhydrides** are of two types, (*a*) those in which two or more phosphoric residues are linked by oxygen atoms to yield diphosphates, triphosphates, etc. (e.g., ADP, ATP, etc.; Table 2) and (*b*) those in which phosphoric acid forms a "mixed anhydride" with a different type of acid (generally a carboxylic acid, e.g., acetic acid) (Table 6). The latter are named (ref. 1, Rule 5.64) as "R-ic phosphoric anhydrides" or as "R-yl phosphates" (e.g., acetic phosphoric anhydride or acetyl phosphate).

Comments. (*i*). "Pyro" should not be used for the substituted phosphoric anhydrides (ref. 6, Rule 4.12) (Table 2), but may be retained in such terms as inorganic pyrophosphate (ref. 6, Rule 5.213), pyrophosphatase, pyrophosphate-glycerol transferase, and pyrophosphorolysis (2). (Compare Section 1 above re "phosphoryl".)

(*ii*) The prefixes di, tri, tetra, etc. should not be used to indicate two or more independent phosphoric residues substituted on different oxygen (or other) atoms in a single compound; the appropriate multiplying prefixes for such compounds are bis, tris, tetrakis, etc. (ref. 1, Rule 5.51; ref. 6, Rules 2.251 and 4.12). For example, "fructose 1,6-diphosphate" could indicate a diphosphoric residue bridging positions 1 and 6 of fructose; the common biochemical substance is correctly named fructose 1,6-bis(phosphate) (ref. 3, Rule 4.4).

4. **Phosphodiesters** (Tables 3 and 4), which involve the bridging group -PO(OH)-, could be named in terms of phosphinic acid, $H_2PO(OH)$, for which the prefix form is phosphinico (1). However, the use of this prefix, as in ref. 2, presents complications in placing the locants for unsymmetrical diesters. Hence, phosphinico is contracted to phospho, which is used as an infix between the names of the two alcohols. Thus, **glycerophosphocholine** is recommended (5) for the well-known substance [previously (8), but incorrectly, called glycerophosphorylcholine; compare Section 1 above]. This recommendation

---

* Document of the IUPAC–IUB Commission on Biochemical Nomenclature (CBN),† approved by IUPAC and IUB in 1976 and published by permission of the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Biochemistry (IUB). Comments and suggestions for future revisions of this document may be sent to any member of CBN.† Reprints may be obtained from the National Research Council Office of Biochemical Nomenclature (W. E. Cohn, Director), Biology Division, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, TN 37830, U.S.A.

† O. Hoffmann-Ostenhof (Chairman), W. E. Cohn (Secretary), A. E. Braunstein, H. B. F. Dixon, B. L. Horecker, W. B. Jakoby, P. Karlson, W. Klyne, C. Liébecq, and E. C. Webb.

also illustrates the convention by which glycerol phosphate is contracted to **glycerophosphate** (8), but this should not be done in a context where "glycero" may be confused with the residue of glyceric acid, as in glycerolactone, or with the prefix *glycero* used in carbohydrate nomenclature (ref. 4, Rule 9). (For the placement of locants, see examples in Tables 1 and 4.)

Comments. (*i*) The use of "phosphoryl" in this situation requires an indication in the name that there is one hydroxyl group remaining on the phosphoric residue, and would thus further lengthen the name (see Section 1 above).

(*ii*) The diacyl derivatives of glycerophosphocholine are commonly expressed as derivatives of phosphatidic acid (Table 4), i.e., diacylglycerophosphocholine ≡ phosphatidylcholine (8).

(*iii*) The trivial names for the acid radicals of nucleotides (Table 3) include the phosphoric residue, hence the latter is not specified in oligo- or polynucleotide names, e.g., adenylylcytidine suffices for Ado-*P*-Cyd (locants omitted for clarity; cf. ref. 9).

(*iv*) The so-called cyclic phosphates (Table 3), of which adenosine 3′,5′-phosphate (cyclic AMP or cAMP) is the best-known example, are named in this form rather than in an inverted form, which would yield 3′,5′-phosphoadenosine. The word "cyclic," often added before "phosphate," is unnecessary if the locants are given.

(*v*) The infix "phospho" gives precedent for "diphospho," "triphospho," "tetraphospho," etc. for the doubly esterified oligophosphoric acids (Table 2), e.g., uridinediphosphoglucose, adenosinediphosphoribose.

5. **Nucleoside Triphosphate Analogs,** in which a methylene group (-CH_2-), an imido group (-NH-), or a sulfur atom replaces an oxygen atom bridging two phosphorus atoms, could be named by an extension of the convention of inorganic nomenclature (ref. 6, Rule 4.15) that employs μ to indicate a bridging group. Thus the compound symbolized as Ado-(5′)*P*[CH_2]*PP* could be named adenosine 5′-(1,2-μ-methylene)triphosphate, and Ado(5′)*PP*[CH_2]*P* might be named adenosine 5′-(2,3-μ-methylene)triphosphate. However, for the "methylene" part of these names, [α,β-methylene] and [β,γ-methylene] are unambiguous, are consistent with the use of Greek letters as locants in other situations (7), and are therefore recommended (see Table 8). (The latter compound can be termed 5′-adenylyl methylenediphosphonate, but this name does not contain the significant term "triphosphate".)

Comments. (*i*) The use of square brackets here is similar to their use in amino-acid replacement (11), indicating a replacement of the normal constituent.

(*ii*) Although the bridging methylene group in the Ado-(5′)*PP*[CH_2]*P* example should receive priority for numbering, i.e., should be 1,2-μ-methylene to accord with inorganic nomenclature (ref. 6, Rule 4.15), this would require an additional term (as in Table 8, column 2); it is therefore not suitable in this context, in which it is desirable to give adenosine first consideration (i.e., it is always considered to be linked to the α phosphorus atom).

(*iii*) A terminal substitution (e.g., sulfur replacing oxygen on P^3) might be named adenosine 5′-[3-thio]triphosphate, but adenosine 5′-[γ-thio]triphosphate is recommended (see *ii* above).

(*iv*) The rules of inorganic nomenclature (ref. 6, Table II) specify "imido" as the ligand name for -NH-; it is, in this case, an imide of phosphoric acid, hence "imido" is recommended for biochemical use with "triphosphate" or "diphosphate" (see Table 8).

(*v*) The symbol for the nucleoside does not include the 5′-oxygen atom when the rest of the formula is written out *in extenso.* Thus, Ado(5′)*P*[CH_2]*P* ≡ Ado(5′)-O-PO(OH)-CH_2-PO_3H_2. Such extended representation may be useful for analogs such as Ado(5′)-CH_2-PO_3H_2, a methylene analog of AMP, and Ado(5′)-O-PO(OH)-CH_2-AsO_3H_2.

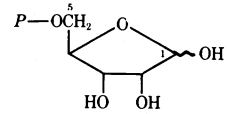
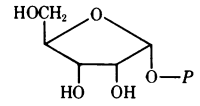
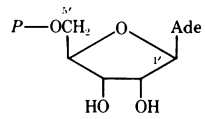
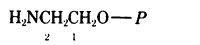
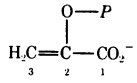
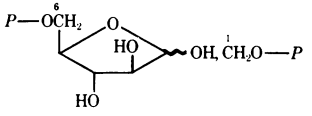
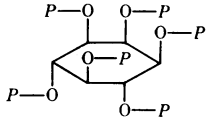
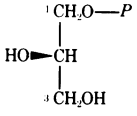
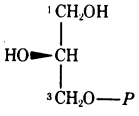
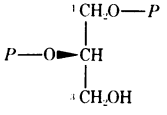
6. **Phosphoric amides** (Table 5) are named by changing "acid" in the original acid name to "amide" (ref. 1, Rule 5.62). However, when the nitrogenous group supplying the amide moiety is known by a trivial name and that name is to be retained, the phosphoric amide may be named in the same manner as the esters (see Section 1 above), but not in the form in which "phosphate" is used as a suffix (see Section 2 above); e.g., *phosphocreatine* (for *N*-phosphonocreatine), but not "creatine phosphate," because the term "phosphate" means that all atoms attached to the phosphorus atom are oxygen atoms.

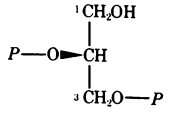
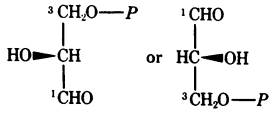
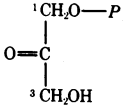
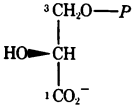
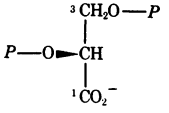
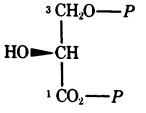
Comment. The contraction "phosphoamide" for phosphoric amide is often seen, but becomes unwieldy when either the amide or the phosphoric residue is substituted. Such compounds should be named as derivatives of phosphoramidic acid (or of a phosphoramidate), or of amidophosphoric acid (amidophosphate) [ref. 1, Rules 5.0(*e*), 5.53(*a, b*), and 5.61(*a, b*)].

7. **Fluorophosphoric acids,** when doubly esterified, become fluorophosphates or phosphorofluoridates [ref. 1, Rules 5.53(*a, b*), 5.61(*a, b*), and 5.0(*e*)]. Thus, the well-known compound $(Pr^iO)_2PO$-F or iPr_2P-F (4) may be called diisopropyl fluorophosphate or diisopropyl phosphorofluoridate (see Table 6).

1. "Nomenclature of Organic Chemistry, Section D," *IUPAC Information Bulletin, Appendix 31, August 1973,* pp. 60–86.
2. *Enzyme Nomenclature (1972),* (Elsevier Scientific Publishing Company, Amsterdam and New York), [Supplement 1: *Biochim. Biophys. Acta* **429,** 1–45 (1976)].
3. "Abbreviations and Symbols for Chemical Names of Special Interest in Biological Chemistry" (1965 Tentative Rules); *Biochem. J.* **101,** 1–7 (1966); *Biochemistry* **5,** 1445–1453 (1966); and elsewhere.
4. "Nomenclature of Carbohydrates" (1969), *Biochemistry* **10,** 3983–4004 (1971); *Eur. J. Biochem.* **21,** 455–477 (1971); and elsewhere.
5. "Nomenclature of Lipids" (1976), *Hoppe-Seyler's Z. Physiol. Chem.,* in press; *Lipids* **12,** 455–468 (1977).
6. *IUPAC Nomenclature of Inorganic Chemistry,* (1970) (Butterworths, London).
7. *IUPAC Nomenclature of Organic Chemistry, Sections A, B, C,* (1971) (Butterworths, London).
8. "The Nomenclature of Lipids" (1967), *J. Biol. Chem.* **242,** 4845–4849 (1967); and **245,** 1511 (1970); and elsewhere. Revision (1976), in press (5).
9. "Abbreviations and Symbols for Nucleic Acids, Polynucleotides, and their Constituents" (1970), *Arch. Biochem. Biophys.* **145,** 425–436 (1971); *Eur. J. Biochem.* **15,** 203–208 (1970); and elsewhere.
10. "Symbols for Amino-Acid Derivatives and Peptides" (Recommendations 1971), *Biochim. Biophys. Acta* **263,** 205–212 (1972); *J. Biol. Chem.* **247,** 977–983 (1972); and elsewhere.
11. "Rules for Naming Synthetic Modfications of Natural Peptides" (Tentative Rules 1966, amended 1972), *Biochemistry* **6,** 362–364 (1975); and elsewhere.
12. "Nomenclature of α-Amino Acids" (Recommendations 1974), *Biochemistry* **14,** 449–462 (1975); *Biochem. J.* **149,** 1–16 (1975); and elsewhere.

Table 1. Phosphoric esters (phosphates)

	Names recommended for biochemical usage[a]				
	Phosphate names	*O*-Phosphono/phospho names	Systematic names	Abbreviations[a,b]	Structure
1.	D-Ribose 5-phosphate	5-*O*-Phosphono-D-ribose; 5-phospho-D-ribose	D-Ribofuranose 5-(dihydrogen phosphate)	ribose-5-*P*; Rib5*P*	
2.	α-D-Ribose 1-phosphate; α-D-ribosyl phosphate[c]	1-*O*-Phosphono-α-D-ribose; 1-phospho-α-D-ribose	α-D-Ribofuranose 1-(dihydrogen phosphate); α-D-ribofuranosyl dihydrogen phosphate[c]	ribose-1-*P*; Rib1*P*	
3.	Adenosine 5′-phosphate; 5′-adenylic acid[d]	5′-*O*-Phosphonoadenosine; 5′-phosphoadenosine	Adenosine 5′-(dihydrogen phosphate)	adenosine-5′*P*; Ado5′*P*; *P*Ado; 5′AMP	
4.	2-Aminoethyl phosphate; 2-aminoethanol *O*-phosphate; 2-aminoethanol phosphate (ester)	2-Amino-*O*-phosphonoethanol; phosphoethanolamine[e]	2-Aminoethyl dihydrogen phosphate; 2-aminoethanol (dihydrogen phosphate) (ester); 2-aminoethanol *O*-(dihydrogen phosphate)	*P*-ethanolamine	
5.	2-Hydroxy-2-propenoate phosphate (ester)	*O*-Phosphono-*enol*-pyruvate; phospho*enol*pyruvate[e]	2-(Phosphonooxy)-2-propenoate; 2-hydroxy-2-propenoate (dihydrogen phosphate) (ester)	*P-enol*pyruvate[f]	
6.	D-Fructose 1,6-bis(phosphate)	1,6-Di-*O*-phosphono-D-fructose; 1,6-bis(phospho)-D-fructose	D-Fructofuranose 1,6-bis(dihydrogen phosphate)	fructose-1,6-P_2; Fru(1,6)P_2	
7.	*myo*-Inositol hexakis(phosphate)[g]	Hexa-*O*-phosphono-*myo*-inositol; hexakis(phospho)-*myo*-inositol	*myo*-Inositol hexakis(dihydrogen phosphate)	P_6-inositol	
8.	*sn*-Glycerol 1-phosphate[h]; *sn*-glycero-1-phosphate	1-*O*-Phosphono-*sn*-glycerol; 1-phospho-*sn*-glycerol	(*S*)-[2,3-Dihydroxypropyl dihydrogen phosphate]; (*S*)-[glycerol 1-(dihydrogen phosphate)]	*sn*-glycerol-1-*P*	
9.	*sn*-Glycerol 3-phosphate[i]; *sn*-glycero-3-phosphate	3-*O*-Phosphono-*sn*-glycerol; 3-phospho-*sn*-glycerol	(*R*)-[2,3-Dihydroxypropyl dihydrogen phosphate]; (*R*)-[glycerol 1-(dihydrogen phosphate)]	*sn*-glycerol-3-*P*	
10.	*sn*-Glycerol 1,2-bis(phosphate)[j]; *sn*-glycero-1,2-bis(phosphate)	1,2-Di-*O*-phosphono-*sn*-glycerol; 1,2-bis(phospho)-*sn*-glycerol	(*S*)-[(Hydroxymethyl)ethylene bis(dihydrogen phosphate)]; (*S*)-[glycerol 1,2-bis(dihydrogen phosphate)]; (*S*)-[2,3-bis(phosphonooxy)-1-propanol]	*sn*-glycerol-1,2-P_2	

11. *sn*-Glycerol 2,3-bis(phosphate)[k]; *sn*-glycero-2,3-bis(phosphate)	2,3-Di-*O*-phosphono-*sn*-glycerol; 2,3-bis(phospho)-*sn*-glycerol	(*R*)-[(Hydroxymethyl)ethylene bis(dihydrogen phosphate)]; (*R*)-[glycerol 1,2-bis(dihydrogen phosphate)]; (*R*)-[2,3-bis(phosphonooxy)-1-propanol]	*sn*-glycerol-2,3-P_2	
12. D-Glyceraldehyde 3-phosphate	3-*O*-Phosphono-D-glyceraldehyde; 3-phospho-D-glyceraldehyde	2-Hydroxy-3-oxopropyl dihydrogen phosphate; 2-formyl-2-hydroxyethyl dihydrogen phosphate; D-glyceraldehyde 3-(dihydrogen phosphate)	D-glyceraldehyde-3-*P*	
13. Glycerone phosphate[l]; 1,3-dihydroxyacetone phosphate	1-*O*-Phosphonoglycerone; 1-phosphoglycerone[l]	3-Hydroxy-2-oxopropyl dihydrogen phosphate; 1-hydroxy-3-(phosphonooxy)-2-propanone	glycerone-*P*[l]; dihydroxyacetone-*P*	
14. D-Glycerate 3-phosphate	3-*O*-Phosphono-D-glycerate; 3-phospho-D-glycerate	(*R*)-[2-Hydroxy-3-(phosphonooxy)-propanoate]; (*R*)-[2,3-dihydroxypropanoate 3-(dihydrogen phosphate)]	D-glycerate-3-*P*	
15. D-Glycerate 2,3-bis(phosphate)[m]	2,3-Di-*O*-phosphono-D-glycerate; 2,3-bis(phospho)-D-glycerate[m]	(*R*)-[2,3-Bis(phosphonooxy)-propanoate]; (*R*)-[2,3-dihydroxypropanoate 2,3-bis(dihydrogen phosphate)]	D-glycerate-2,3-P_2	
16. (D-Glyceroyl phosphate) 3-phosphate[n]	3-*O*-Phosphono-D-glyceroyl phosphate; 3-phospho-D-glyceroyl phosphate; 3-*O*-phosphono-D-glyceric phosphoric monoanhydride; 3-phospho-D-glyceric phosphoric monoanhydride	2-Hydroxy-3-(phosphonooxy)-propionyl dihydrogen phosphate; 2,3-dihydroxypropionyl dihydrogen phosphate 3-(dihydrogen phosphate); 2-hydroxy-3-(phosphonooxy)-propionic phosphoric monoanhydride	D-glyceric-1,3-P_2	

[a] See Section 2 in the *text*. Stereospecific numbering denoted by *sn* is defined in ref. 8. If fully defined in a paper, *sn* and D may be omitted from biochemical names and abbreviations.

[b] The symbol *P* represents a phosphoric residue and may precede or follow the organic residue. Approved symbols, such as Rib, Ado, Fru, etc. (refs. 3, 9, and 10) are used to represent the organic residues. The symbols Ins, for inositol, and Gro, Gra, Grn, Gri, for glycerol, glyceraldehyde, glycerone (see footnote l, below), and glyceric acid, respectively, are defined in ref. 5.

[c] Locants are not needed because the glycosyl radical, by definition, is formed at the hemiacetal position (ref. 4).

[d] Nucleotide trivial name.

[e] Most commonly used name.

[f] "Pyruvenol" with the symbol *e*Prv has been suggested for "*enol*pyruvate."

[g] Phytic acid.

[h] Previously named either L-glycerol 1-phosphate or D-glycerol 3-phosphate (refs. 5 and 8). Originally named L-glycerol 1-phosphate or D-α-glycerophosphoric acid (ref. 3).

[i] Previously named L-glycerol 3-phosphate or D-glycerol 1-phosphate (refs. 5 and 8). Originally named D-glycerol 1-phosphate or L-α-glycerophosphoric acid (ref. 3).

[j] Previously named L-glycerol 1,2-bis(phosphate) or D-glycerol 2,3-bis(phosphate).

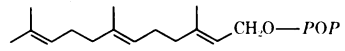
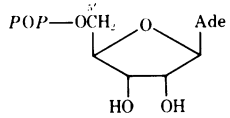
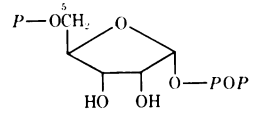
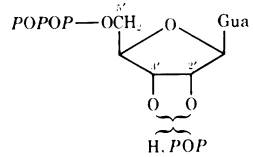
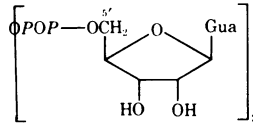
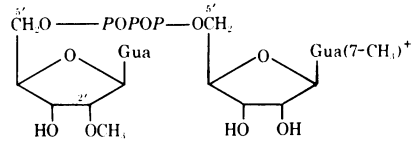
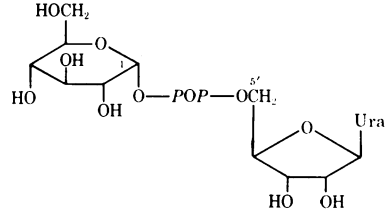
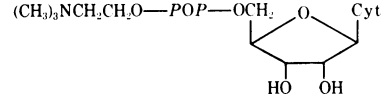
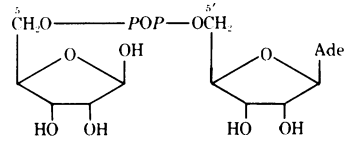
[k] Previously named D-glycerol 1,2-bis(phosphate) or L-glycerol 2,3-bis(phosphate).

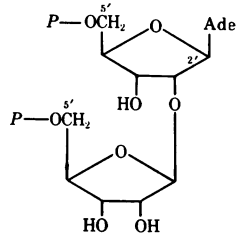
[l] The name "glycerone" has been proposed for 1,3-dihydroxyacetone (ref. 5).

[m] Often called "diphosphoglycerate"; "bis" is correct (see Section 3).

[n] One phosphoric residue is an ester; the other is an anhydride. Glyceroyl is the acyl radical derived from glyceric acid (ref. 7, Rule C-411.1).

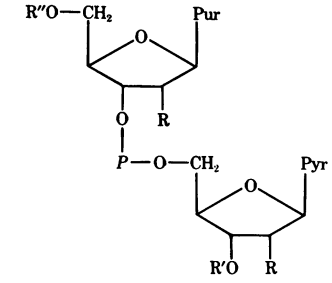
Table 2. Representative oligophosphoric esters (oligophosphates)

Recommended names	Other names	Abbreviations[a]	Structure
1. Farnesyl diphosphate; farnesol diphosphate	Farnesyl trihydrogen diphosphate; farnesol (trihydrogen diphosphate)		
2. Adenosine 5′-diphosphate[b]	5′-Diphosphoadenosine; 5′-adenylyl phosphate	adenosine-5′*PP*; Ado5′*PP*; *PP*Ado; ADP	
3. 5-Phospho-α-D-ribosyl diphosphate[c]; α-D-ribosyl diphosphate 5-phosphate	5-*O*-Phosphono-α-D-ribosyl diphosphate; 5-phospho-α-D-ribofuranosyl diphosphate; 1-diphospho-5-phospho-α-D-ribofuranose; α-D-ribose 1-diphosphate 5-phosphate	*PP*Rib*P*[d]; *P*Rib-*PP*	
4. Guanosine 2′ (or 3′)-diphosphate 5′-triphosphate	2′(or 3′)-Diphospho-5′-triphosphoguanosine; 2′(or 3′)-diphosphoguanylyl triphosphate	pppGpp; p_3Gp_2	
5. Guanosine(5′)tetraphospho(5′)-guanosine; bis(guanylyl) diphosphate	P^1,P^4-Bis(5′-guanosyl) tetraphosphate; bis(5′-guanylyl) diphosphate	G(5′)p_4(5′)G; $(ppG)_2$	
6. 7-Methylguanosine(5′)triphospho(5′)-2′-*O*-methylguanosine[e]	P^1-(7-Methyl-5′-guanosinium-5′-yl) P^3-(2′-*O*-methyl-5′-guanosyl) triphosphate; 7-methylguanosinium 5′-(2′-*O*-methylguanosine 5′-triphosphate)	m^{7}G(5′)ppp-(5′)Gm	
7. Uridine(5′)diphospho(1)-α-D-glucose[c]	Uridine diphosphate glucose; uridine 5′-(α-D-glucopyranosyl diphosphate); α-D-glycopyranosyl 5′-uridylyl phosphate	UDP-Glc; U5′pp1Glc; UDPG[f]	
8. Cytidine(5′)diphosphocholine[c]	Cytidine diphosphate choline; cytidine 5′-(choline diphosphate); choline (5′-cytidylyl phosphate)	CDP-choline; CDP-Cho	
9. Adenosine(5′)diphospho(5)-β-D-ribose[c,g]	Adenosine diphosphate ribose; adenosine 5′-(β-D-ribose 5-diphosphate)	ADP-Rib; A5′pp5Rib; (Rib5)ppA	

10. 2′-(5-Phospho-β-D-ribosyl)-adenosine 5′-phosphate[c,g]	2′-(5-Phospho-β-D-ribofuranosyl)adenosine 5′-phosphate; 2′-(5-phospho-β-D-ribofuranosyl)-5′-adenylic acid	AMP(*P*-Rib); *P*-Ado(*P*-Rib); pA2′(pRib); pRib(1-2′)pA; iso(ADP-Rib); ψ ADP-Rib[h]	

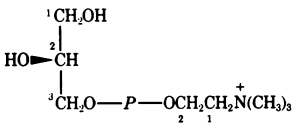
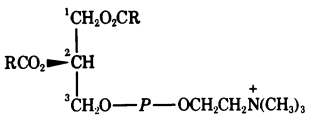
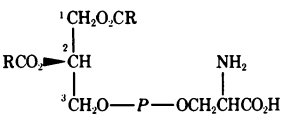
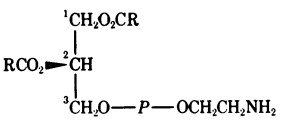
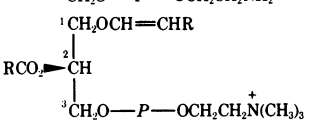
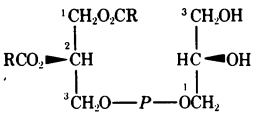
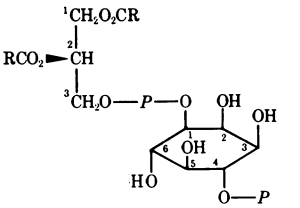
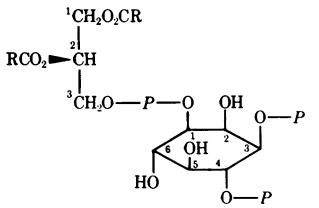
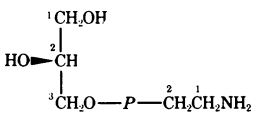
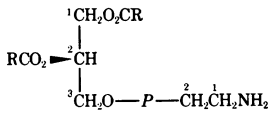
[a] The symbol Rib for the ribose residue is defined in ref. 3. Other symbols are defined in ref. 9, especially *P* or p = phosphoric residue.
[b] Triphosphates are treated similarly. Analogs of ATP are further delineated in Table 6. Other nucleoside terms may replace "adenosine," "adenylyl," and "Ado" (ref. 9).
[c] Locants and descriptors are customarily omitted for the isomers shown, so that the terms may be written as, e.g., phosphoribosyl diphosphate, uridinediphosphoglucose (compound 7).
[d] The abbreviation PPRP is seen often in the literature; it is not recommended.
[e] Bis(nucleotides) of this type, including the methylation as shown, appear to be the common 5′-terminus of many, if not all, of the RNAs of RNA-containing viruses. The use of 7-methylguanosine instead of the more correct 7-methyl-7-guanosinium is common.
[f] Common, but can be ambiguous in context with galactose. Glc for glucose is preferred.
[g] Cleavage of "poly(ADP-Rib)" at the 2′ linkage of the adenosine moieties gives compound 9, and between the phosphoric residues gives compound 10. Although compound 10 is not an oligophosphoric ester and does not really belong in this table, it is included because it is most often encountered in conjunction with the isomeric compound 9.
[h] Disfavored; given here because of occurrence in the literature. (Ψ has other meanings in this context.)

Table 3. Representative bisnucleoside phosphates and cyclic phosphates (3, 9).

Recommended name[a]	Other name[b]	Abbreviations	General structure[c]
1. Adenylyl(3′-5′)cytidine	Cytidylyl(5′→3′)adenosine	A-C; Ado-3′*P*5′-Cyd	
2. Adenylyl(3′-5′)cytidine 3′-phosphate	3′-Phosphocytidylyl(5′→3′)adenosine	A-Cp; Ado-3′*P*5′-Cyd*P*	
3. 5′-Phosphoadenylyl(3′-5′)cytidine 3′-phosphate	3′-Phosphocytidylyl(5′→3′)adenosine 5′-phosphate	pA-Cp; *P*Ado-3′*P*5′-Cyd*P*	
4. 5′-Phosphodeoxyadenylyl(3′-5′)-thymidine[d]	Thymidylyl(5′→3′)deoxyadenosine 5′-phosphate	pdA-dT; d(pA-T); *P*-dAdo-3′*P*5′-dThd	
5. 5′-Triphosphoguanylyl(3′-5′)cytidine	Cytidylyl(5′→3′)guanosine 5′-triphosphate	pppG-C	
6. Cytidine 2′,3′-phosphate	Cytidine 2′,3′-(cyclic)phosphate[e]	Cyd>*P*; Cyd-2′,3′-*P*; C>p	
7. Adenosine 3′,5′-phosphate	Adenosine 3′,5′-(cyclic)phosphate[e]	Cyclic AMP; cAMP; Ado-3′,5′-*P*	

[a] The infix (3′–5′) may be omitted if no ambiguity may arise.
[b] Many other names, including permutations of those given, are possible, e.g., adenosine(3′)-phospho(5′)cytidine and 5′-(3′-adenylyl)cytidine for compound 1.
[c] General structure for entries 1–5: R = OH in entries 1, 2, 3, and 5; H in 4. R′ = H in 1, 4, and 5; *P* in 2 and 3. R″ = H in 1 and 2; *P* in 3 and 4; *POPOP* in 5.
[d] The prefix "ribo" precedes "thymidine" when 5-methyluridine is meant. The symbols Thd and T indicate the latter; dThd and dT represent thymidine (3, 9).
[e] "(Cyclic)" is redundant when locants are given in compounds 6 and 7, but is helpful. It is necessary when, in repeated usage, the locants are omitted.

Table 4. Representative phospholipids (involving diesterified phosphoric acid)

Recommended name[a,b]	Other names	Abbreviations[c]	Structure
1. *sn*-Glycero(3)phosphocholine	Glycerol choline phosphate	Gro*P*Cho	
2. (3-*sn*-Phosphatidyl)choline	1,2-Diacyl-*sn*-glycero(3)phosphocholine; lecithin[d]	PtdCho; acyl$_2$Gro*P*Cho	
3. (3-*sn*-Phosphatidyl)-L-serine	1,2-Diacyl-*sn*-glycero(3)-L-phosphoserine; cephalin[d]	PtdSer; acyl$_2$Gro*P*Ser	
4. (3-*sn*-Phosphatidyl)ethanolamine	1,2-Diacyl-*sn*-glycero(3)phosphoethanolamine; cephalin[d]	PtdEtn; acyl$_2$Gro*P*Etn	
5. 2-Acyl-1-(1-alkenyl)-*sn*-glycero(3)phosphocholine	Plasmenylcholine[e]; plasmalogen		
6. 1-(3-*sn*-Phosphatidyl)-*sn*-glycerol	1,2-Diacyl-*sn*-glycero(3)-phospho(1)-*sn*-glycerol	PtdGro	
7. 1-(3-*sn*-Phosphatidyl)-L-*myo*-inositol	1,2-Diacyl-*sn*-glycero(3)-phospho(1)-L-*myo*-inositol; phosphoinositide[d]	PtdIns	
8. 1-(3-*sn*-Phosphatidyl)-L-*myo*-inositol 4-phosphate	1,2-Diacyl-*sn*-glycero(3)phospho(1)-L-*myo*-inositol 4-phosphate; 1,2-diacyl-*sn*-glycero(3)phospho(1)-4-phospho-L-*myo*-inositol; phosphoinositide 4-phosphate[d]; diphosphoinositide[d]	PtdIns4*P*	
9. 1-(3-*sn*-Phosphatidyl)-L-*myo*-inositol 3,4-bis(phosphate)	1,2-Diacyl-*sn*-glycero(3)phospho(1)-L-*myo*-inositol 3,4-bis(phosphate); 1,2-diacyl-*sn*-glycero(3)-phospho(1)-3,4-bis(phospho)-L-*myo*-inositol; phosphoinositide 3,4-bis(phosphate)[d]; triphosphoinositide[d]	PtdIns(3,4)P_2	
10. *sn*-Glycero(3)-2-phosphonoethylamine[f]	*sn*-Glycerol 3-[(2-aminoethyl)-phosphonate]	Gro*P*EtNH$_2$	
11. (3-*sn*-Phosphatidyl)-ethylamine[f]	1,2-Diacyl-*sn*-glycero(3)-2-phosphonoethylamine	PtdEtNH$_2$	

[a] Stereospecific numbering denoted by *sn* is defined in ref. 8. If fully defined in a paper, *sn* and various locants and descriptors may be omitted from the recommended names and abbreviations. The infix "phospho" replaces "phosphoryl" and "phosphinico," which have been used in the past (refs. 2 and 3) (see Sections 1 and 4 of the *text*).

[b] Phosphatidyl = 1,2-diacyl-*sn*-glycero(3)phospho, which may replace it when desired. For *O*-alkenyl- and *O*-alkyl-substituted glycero compounds ("lyso" compounds), see entry 5 and ref. 5.

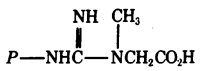
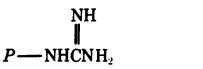
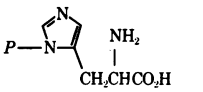
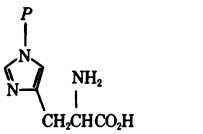
[c] The symbols Ptd for phosphatidyl, Gro for glycerol, Cho for choline, Ser for serine, Etn for ethanolamine, Ins for inositol, and *P* for a phosphoric residue are defined in ref. 5.

[d] Trivial names occasionally used in the past; not recommended. Included here only for reference.

[e] Plasmenyl and plasmanyl are defined in ref. 5.

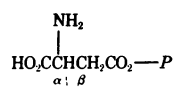
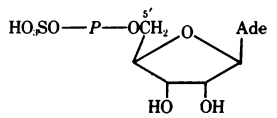
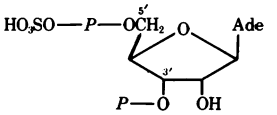
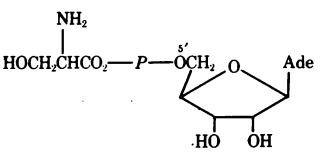
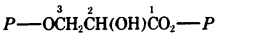
[f] Phosphonic derivatives, containing a P-C bond (compare entry 4, also Table 7).

Table 5. Phosphoric amides (phosphoramidic acids or amidophosphoric acids)

Recommended names[a]	Other names[b,c]	Structure
1. Phosphocreatine	N^{ω}-Phosphonocreatine; *N*-(*N*-Phosphonoamidino) sarcosine	
2. Phosphoglycocyamine	N^{ω}-Phosphonoglycocyamine; N^{ω}-phosphonoguanidinoacetic acid; *N*-(*N*-phosphonoamidino)glycine	
3. Phosphoguanidine	*N*-Amidinophosphoramidate; *N*-amidinophosphoramidic acid	
4. *pros*-Phosphohistidine[d]; π-phosphohistidine	3(1)-Phosphonohistidine[c]	
5. *tele*-Phosphohistidine[d]; τ-phosphohistidine	1(3)-Phosphonohistidine[c]	

[a] See Section 6 of the *text* for a discussion of the reasons for not using the "phosphate" form of name for the phosphoric amides. *P*-Creatine and creatine-*P* are valid for abbreviation purposes, on the assumption that the hyphen indicates a covalent bond; names such as creatine phosphate do not indicate a covalent bond.
[b] The symbol ω is used to mean the NH_2 terminal group.
[c] The prefix "phosphonato" may be used to indicate an ionic form (ref. 1, Rule 5.52).
[d] For definition of *pros* (π) and *tele* (τ) locants, see refs. 10 and 12.

Table 6. Representative phosphoric anhydrides and fluorophosphates[a]

Recommended names	Other names	Abbreviations	Structure
1. Acetyl phosphate	Monoacetyl phosphate; acetic phosphoric monoanhydride	Ac-*P*	$CH_3CO_2—P$
2. β-Aspartyl phosphate	Mono-β-aspartyl phosphate; β-aspartic phosphoric monoanhydride	Asp(βP)	
3. Carbamoyl phosphate[b]	Monocarbamoyl phosphate; carbamic phosphoric monoanhydride	Cbm-*P*	$H_2NCO_2—P$
4. Adenosine 5′-phosphosulfate	Adenosine 5′-*P*-phosphatosulfate[c]; 5′-adenylyl sulfate; 5′-adenylic sulfuric monoanhydride	APS[d]; Ado*PS*	
5. Adenosine 3′-phosphate 5′-phosphosulfate; 3′-phosphoadenosine 5′-phosphosulfate	Adenosine 3′-phosphate 5′-*P*-phosphatosulfate[c]; 3′-phospho-5′-adenylyl sulfate; 3′-phospho-5′-adenylic sulfuric monoanhydride	PAPS[d]; *P*Ado*PS*	
6. Seryl adenylate	1-*O*-(5′-Adenylyl)serine; adenosine(5′)phospho(1)-serine	AMP-Ser; Ser-*P*-Ado	
7. 3-Phosphoglyceroyl phosphate[e]	3-*O*-Phosphonoglyceric phosphoric monoanhydride; (glyceroyl phosphate) 3-phosphate	Gri(1,3)P_2[f]	
8. Diisopropyl fluorophosphate	Diisopropyl phosphorofluoridate	iPr_2P-F[g]	$[(CH_3)_2CHO]_2P(O)F$

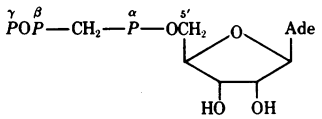
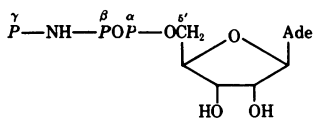
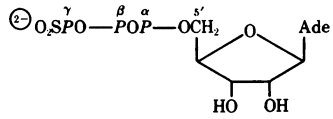
[a] See Sections 3 and 7 in *text*.
[b] "Carbamyl," which is often used, is not in accord with the Organic Rules (ref. 10, Rule 431.2).
[c] See Rules of Inorganic Nomenclature (ref. 6, Rule 4.211).
[d] Commonly used in the literature; Ado form is preferred for A and *P* and *S* for the acid residues.
[e] See entry 16 in Table 1.
[f] See footnote b in Table 1.
[g] Equivalent to DIPF, FDIP, DFP, and Dip-F (ref. 10).

Table 7. Representative *C*-phosphonates

Recommended name	Other names[a]	Structure
1. (2-Aminoethyl)phosphonic acid[b]	2-Phosphonoethylamine; ciliatine	$P—\overset{2}{C}H_2\overset{1}{C}H_2NH_2$
2. (2-Oxoethyl)phosphonic acid	(Formylmethyl)phosphonic acid; phosphonoacetaldehyde	$P—CH_2CHO$

[a] The prefix "phosphonato" may be used to indicate an ionic form (ref. 1, Rule 5.52).
[b] See also entries 10 and 11 in Table 4.

Table 8. Adenosine 5′-triphosphate analogs[a]

Recommended name	Other names[b]	Abbreviations	Structure
1. Adenosine 5′-[α,β-methylene]-triphosphate	Adenosine (5′→O^1)-1,2-μ-methylenetriphosphate; adenosine (5′→P^1)-1,2-μ-methylenetriphosphate	Ado*P*[CH_2]*PP*; pp[CH_2]pA	
2. Adenosine 5′-[β,γ-imido]-triphosphate	Adenosine (5′→O^3)-1,2-μ-imidotriphosphate; adenosine (5′→P^3)-1,2-μ-imidotriphosphate; 5′-adenylyl imidodiphosphate; 5′-adenylyl iminodiphosphonate[c]	Ado*PP*[NH]*P*; p[NH]ppA	
3. Adenosine 5′-[γ-thio]-triphosphate	Adenosine (5′→O^3)-1-thiotriphosphate; adenosine (5′→P^3)-1-thiotriphosphate	Ado*PPP*[S]; [S]pppA; ATP[S]	

[a] See Section 5 in *text*.
[b] Adaptation of principles of inorganic nomenclature for isopolyanions (ref. 6, Rule 4.15).
[c] "Iminodiphosphonate" is derived from organic nomenclature principles (ref. 7, Rules B–15.1, C–815.1).