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FINDING A RATIONAL NOMENCLATURE FOR
MESONS AND BARYONS

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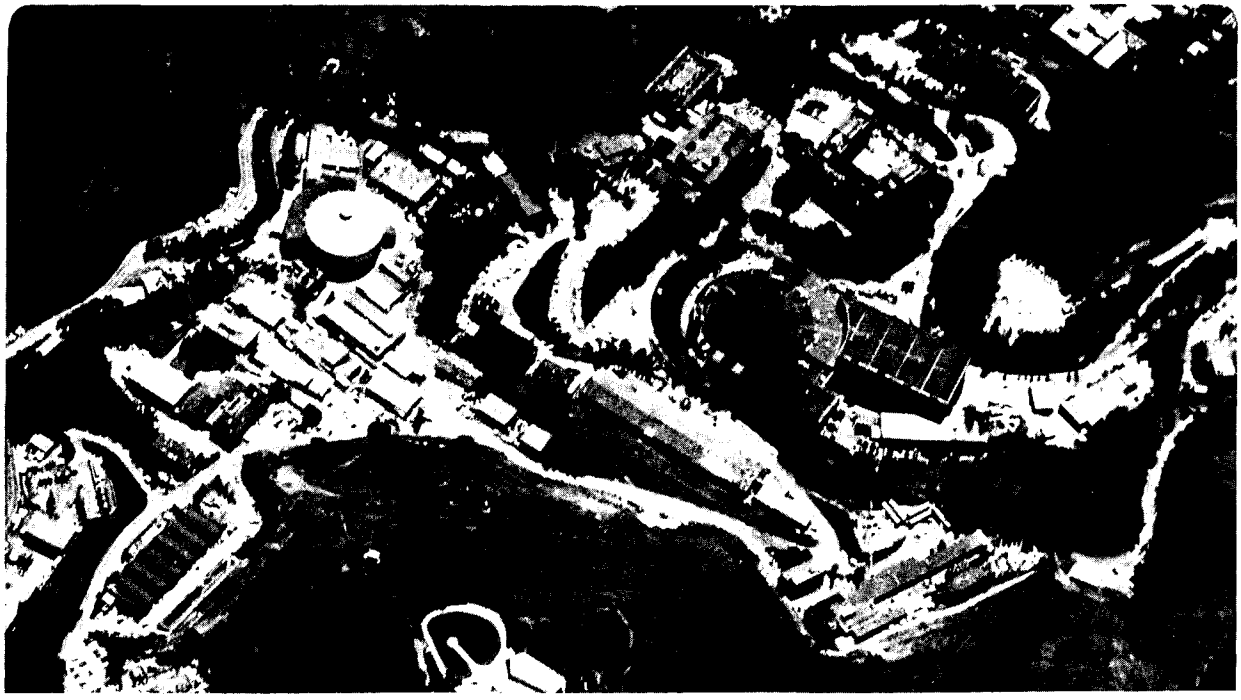

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R.M. Barnett, R.N. Cahn, G. Gidal, A. Rittenberg, T.G. Trippe, C.G. Wohl, and G.P. Yost
Lawrence Berkeley Laboratory,† University of California, Berkeley, CA 94720, USA

F.C. Porter
Department of Physics, California Institute of Technology, Pasadena, CA 91125, USA

J.J. Hernandez and L. Montanet
CERN, European Laboratory for Particle Physics, CH-1211 Geneva 23, Switzerland

M. Roos and N.A. Törnqvist
Department of High Energy Physics, University of Helsinki, SF-00170 Helsinki 17, Finland,
and CERN, European Laboratory for Particle Physics, CH-1211 Geneva 23, Switzerland

M. Aguilar-Benitez
Junta de Energia Nuclear, Madrid 3, Spain, and
CERN, European Laboratory for Particle Physics, CH-1211 Geneva 23, Switzerland

G.J. Feldman
Stanford Linear Accelerator Center, Stanford, CA 94305, USA

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ABSTRACT

A history of the Particle Data Group's efforts to find a rational and systematic convention for naming mesons and baryons is given. Several versions of our proposal are reviewed, and name changes which would occur are summarized. Some of the mail we have received is described. We hope to stimulate additional feedback.

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Particle nomenclature is not a deep or profound topic, but the response to the Particle Data Group's proposal[1] to find a systematic naming convention shows that the historical origins of nomenclature can evoke strong feelings. However, the high energy physics community appears to be united in supporting our efforts to apply limitations to the proliferation of uninformative names. As a result it appears possible to settle on a scheme that is acceptable to virtually the entire community.

The need for a change is reflected in the fact that f, f′, ϵ, S^*, D (1285), E, θ, and h all have the same P, the same C, the same G and the same I. They differ only in spin J and to some extent in quark content. Clearly it would make more sense to have a single name with J indicated by a subscript. (The prime would indicate $s\bar{s}$ content as used currently.) The mass would continue to be part of the name. Another problem is that A_2 and A_3, B (1235) and B (5270), and D (1285) and D (1865) have *different* quantum numbers. Clearly they should have different names.

This is not the first venture of the Particle Data Group into changing nomenclature. The baryon names were changed 20 years ago. In the April 1963 edition of the Tables $N^*_{1/2}$ and $N^*_{3/2}$ (and others) appeared. In the March 1965 edition the names were not changed but the group title for $N^*_{1/2}$'s was identified as N while the group title of $N^*_{3/2}$'s was identified as Δ (plus similar modifications). By January 1967 the names had changed but the group titles were identified as $N^*_{1/2}$ and $N^*_{3/2}$'s. Finally in the January 1968 edition only N and Δ appeared.

Recent efforts were initiated in 1983 by the European portion of the Particle Data Group which is centered at CERN. Discussion continued within and between the LBL and CERN groups into 1984. In August 1984 Lucien Montanet brought the CERN group's ideas to a meeting in Berkeley at which we drafted a tentative proposal. In September 1984 the proposal was discussed with the LBL group's advisory committee (G. Feldman, M. Lederer, C. Quigg, R. Thun, and L. Wolfenstein) and division head (G. Trilling), and they suggested several modifications. The CERN group independently suggested very similar changes, and so the proposal was modified.

The next step during September and October was to communicate the proposal to several leading experimental and theoretical spectroscopists across the United States and in other countries. Their responses led us to make further changes. Then on November 1, 1984 the proposal was presented to the Santa Fe APS meeting. Considerable feedback resulted from this well-attended meeting. Among the continuing modifications was the decision to retain the name J/ψ rather than change it to ψ due to strong feelings in a segment of our community.

Recently a Physics Today article (March 1985) discussed our proposal and suggested that readers send their reactions to us. In April 1985 we mailed copies of our proposal to 6500 physicists requesting responses. At this International Conference on Hadron Spectroscopy we are hoping to stimulate further discussion, so that we can have some further feedback before soon finalizing the proposal.

We have learned that our scheme for naming baryons (particularly the heavy baryons) is identical to schemes proposed earlier by A. Hendry and D. Lichtenberg[2] and by N. Samios[3]. We have received no objections at all for the baryon scheme and considerable support for it. The scheme is

3 u and/or d quarks		
No s quarks	→	N or Δ
2 u and/or d quarks		
1 s quark	→	Λ or Σ
No s quarks	→	Λ_c or Σ_c (etc.)
1 u and/or d quark		
2 s quarks	→	Ξ
1 s quark	→	Ξ_c or Ξ_b (etc.)
No s quarks	→	Ξ_{cc} or Ξ_{cb} (etc.)
No u or d quarks		
3 s quarks	→	Ω
2 s quarks	→	Ω_c or Ω_b (etc.)
1 s quark	→	Ω_{cc} or Ω_{cb} (etc.)
No s quarks	→	Ω_{ccc} or Ω_{ccb} (etc.)

A summary of our proposal for naming mesons is given in Table I. Tables II a - c which will be discussed later are slight variations of Table I involving fewer names. An important point not shown in the tables is that the spin J of each meson will be indicated by a subscript (except for pseudoscalars and vectors). In the scheme of Table I the name of a particle uniquely defines its J, P, C, I, and G. Further details are given in our proposal[1].

Table I. Names of mesons not carrying strange or heavy quantum numbers.*

$q\bar{q}$ content	$J^{PC} = 0^{-+}, 2^{-+}, \cdots$ $^{2S+1}L_J =$ $^1(\text{L even})_J$	$1^{+-}, 3^{+-}, \cdots$ $^1(\text{L odd})_J$	$1^{--}, 2^{--}, \cdots$ $^3(\text{L even})_J$	$0^{++}, 1^{++}, \cdots$ $^3(\text{L odd})_J$
I = 1 (u,d)	π	b	ρ	a
I = 0 (u,d)	$\left\{\begin{matrix}\eta \\ \eta'\end{matrix}\right\}$	$\left\{\begin{matrix}h \\ h'\end{matrix}\right\}$	ω	f
$s\bar{s}$			ϕ	f′
$c\bar{c}$	η_c	h_c	ψ†	χ
$b\bar{b}$	η_b	h_b	Υ	χ_b
$t\bar{t}$	η_t	h_t	θ	χ_t

*States with exotic J^{PC} (0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, $\cdots$) have not been discovered and are not named in this proposal.

†The $c\bar{c}$ state at 3100 MeV would be an exception and be called J/ψ.

For K mesons (and similarly D, B and T mesons) C is not a good quantum number so a slightly different scheme is necessary:

"Abnormal" spin - parity $J^P = 0^-, 1^+, 2^-, 3^+, \ldots$	"Normal " spin - parity $J^P = 0^+, 1^-, 2^+, 3^-, \ldots$
K	K^*

The letters K, D, B, and T indicate the heaviest flavor (quark) in the meson; the lightest flavor (if not u or d) is given by a subscript, e.g., F becomes D_s.

We should consider what happens to the names of our favorite particles. For Table I all changes are shown below:

Names which do not change are:

π, η, ρ, ω, η', ϕ, $\pi(1300)$, $\rho(1600)$, $\phi(1680)$, $\eta_c(2980)$, $J/\psi(3100)$, $\chi(3415)$, and $\Upsilon(9460)$.

Names which have only minor changes are:

f(1270)	becomes	$f_2(1270)$	$A_1(1270)$	becomes	$a_1(1270)$
f'(1525)	"	$f'_2(1525)$	$A_2(1320)$	"	$a_2(1320)$
$\omega(1670)$	"	$\omega_3(1670)$	$\phi(1850)$	"	$\phi_3(1850)$
B(1235)	"	$b_1(1235)$	H(1190)	"	$h_1(1190)$

Major changes are:

$\epsilon(1300)$	becomes	$f_0(1300)$	$\delta(980)$	becomes	$a_0(980)$
$S^*(975)$	"	$f'_0(975)$	$\iota(1440)$	"	$\eta(1440)$
D(1285)	"	$f_1(1285)$	$A_3(1680)$	"	$\pi_2(1680)$
E(1420)	"	$f'_1(1420)$	g(1690)	"	$\rho_3(1690)$
$\theta(1690)$	"	$f'_2(1690)$	h(2030)	"	$f_4(2030)$

For the mesons with strange or heavy quantum numbers the changes are:

$Q_1(1280)$	becomes	$K_1(1280)$	$\kappa(1350)$	becomes	$K_0^*(1350)$
$Q_2(1400)$	"	$K_1(1400)$	$K^*(1430)$	"	$K_2^*(1430)$
L (1770)	"	$K_2(1770)$	$K^*(1780)$	"	$K_3^*(1780)$
F	"	D_s	$K^*(2060)$	"	$K_4^*(2060)$

Let us consider the variations of Table I. We are hoping to receive more feedback as to which variation is preferred. Whereas in Table I, B(1235) became $b_1(1235)$ and H(1190) became $h_1(1190)$, in Tables II the B(1235) becomes $\pi_1(1235)$ while H(1190) becomes $\eta_1(1190)$ thereby eliminating one entire column from Table I. Those advocating this deletion believe it is uneconomical and unwise to invent 6 names for only 2 particles. Note that a consequence of this deletion is that the first column (π, η) no longer uniquely defines P, C or G although they *are* uniquely defined once J is specified (in the subscript). The series J^{PC} remains well-defined. We wish to know public opinion on the relative merits of economy versus uniqueness (before J is specified).

Table IIa. **Alternative** names of mesons not carrying strange or heavy quantum numbers.

$q\bar{q}$ content / J^{PC} =	$0^{-+}, 1^{+-}, \cdots$	$1^{--}, 2^{--}, \cdots$	$0^{++}, 1^{++}, \cdots$
$^{2S+1}L_J$ =	$^1(\text{any L})_J$	$^3(\text{L even})_J$	$^3(\text{L odd})_J$
I = 1 (u,d)	π	ρ	a
I = 0 (u,d)	$\left\{\begin{matrix}\eta\\ \eta'\end{matrix}\right\}$	ω	f
$s\bar{s}$		ϕ	f′
$c\bar{c}$	η_c	$\psi^\dagger$	χ
$b\bar{b}$	η_b	Υ	χ_b
$t\bar{t}$	η_t	θ	χ_t

†The $c\bar{c}$ state at 3100 MeV would be an exception and be called J/ψ.

One can eliminate the only 2 Roman letters for nonstrange, nonheavy particles in Table IIa by changing a $\rightarrow \delta$ and f $\rightarrow \epsilon$ as shown in Table IIb. Here the choice is between aesthetics and historical names.

Table IIb. **Alternative** names of mesons not carrying strange or heavy quantum numbers.

$q\bar{q}$ content / J^{PC} =	$0^{-+}, 1^{+-}, \cdots$	$1^{--}, 2^{--}, \cdots$	$0^{++}, 1^{++}, \cdots$
$^{2S+1}L_J$ =	$^1(\text{any L})_J$	$^3(\text{L even})_J$	$^3(\text{L odd})_J$
I = 1 (u,d)	π	ρ	δ
I = 0 (u,d)	$\left\{\begin{matrix}\eta\\ \eta'\end{matrix}\right\}$	ω	ϵ
$s\bar{s}$		ϕ	ϵ'
$c\bar{c}$	η_c	$\psi^\dagger$	χ
$b\bar{b}$	η_b	Υ	χ_b
$t\bar{t}$	η_t	θ	χ_t

†The $c\bar{c}$ state at 3100 MeV would be an exception and be called J/ψ.

In Table IIc a further reduction in particle names is accomplished by letting ϵ (f in Table IIa) become χ. This forces the change $\chi \rightarrow \chi_c$ for the charm states. While this brings a balance between the first and third columns, there is a danger of some confusion in the literature when χ is used; it could mean $\chi(3415)$ in the old system or $\chi(1270)$ in the new system. The choice here then is between reduction in number of names and possible confusion. We hope to hear further opinions on these four schemes.

Table IIc. **Alternative** names of mesons not carrying strange or heavy quantum numbers.

$q\bar{q}$ content \ J^{PC} =	$0^{-+}, 1^{+-}, \cdots$	$1^{--}, 2^{--}, \cdots$	$0^{++}, 1^{++}, \cdots$
$2S+1L_J$ =	$^1(\text{any L})_J$	$^3(\text{L even})_J$	$^3(\text{L odd})_J$
I = 1 (u,d)	π	ρ	δ
I = 0 (u,d)	$\left\{\begin{matrix}\eta \\ \eta'\end{matrix}\right\}$	ω	χ
$s\bar{s}$		ϕ	χ'
$c\bar{c}$	η_c	ψ†	χ_c
$b\bar{b}$	η_b	Υ	χ_b
$t\bar{t}$	η_t	θ	χ_t

†The $c\bar{c}$ state at 3100 MeV would be an exception and be called J/ψ.

Finally I would like to summarize the reactions we have received to our proposals. From many conversations, we have observed that the people who felt no need to write to us were usually quite pleased with the proposal. Even among those writing, the letters were frequently prefaced with remarks such as: "I applaud the Particle Data Group's proposal to systematize the naming of the mesons and baryons. This $\cdots$ better reflects the state of our current understanding of the simple underlying substructure of these composite states." Or "This proposal is excellent."

For those letters with specific comments, the largest amount of mail argued that we should keep the name J/ψ, and we will keep it. Others argued for the following changes

$$\left.\begin{matrix}\phi \rightarrow \omega' \\ \psi \rightarrow \omega_c \\ \Upsilon \rightarrow \omega_b \\ \theta \rightarrow \omega_t\end{matrix}\right\} \text{ or } \left\{\begin{matrix} \\ \psi \rightarrow \phi_c \\ \Upsilon \rightarrow \phi_b \\ \theta \rightarrow \phi_t\end{matrix}\right.$$

One letter suggested: ψ_c, ψ_b and ψ_t. Several respondents argued that we should use ψ instead of J/ψ.

Our mail has been divided among Tables I, IIa-c; the reactions have been quite varied with no evident pattern. One supporter of Table I suggested using

another letter for b (such as i) and reserving b for the b quark.

One writer suggested keeping F rather than D_s for the $c\bar{s}$ meson. Another proposed changing D mesons ($\bar{u}c$, $\bar{d}c$,...) to C mesons. It was also pointed out that the historical identification $s \rightarrow \bar{K}$ and $b \rightarrow \bar{B}$ is unfortunate.

While we intend to keep the old (colloquial) names next to the new names for some time, it was suggested by some that the colloquial names be retained forever to facilitate conversation. The writer said that "S^*" is easier to say than "$f'_0(975)$," although I presume we would in conversation say "f(975)". Another suggestion was that a Table of historical (colloquial) names be maintained forever to help future students read old literature. I believe this idea should be implemented.

One letter proposed the changes $f \rightarrow \omega$, $f' \rightarrow \phi$ and $\chi \rightarrow \psi$ thereby reducing the number of names. Another economy-minded writer argued that our scheme still has too many names (π, η, b, h, ρ,ω, ϕ, ψ, Υ, a, f, χ, K, D, B, T). His scheme is:

	I = 1	I = 1/2	I=0
S = 0 spin (singlet)	π	K	η
S = 1 (triplet)	ρ	K^*	ω

With this scheme $D \rightarrow K_c$, $B \rightarrow K_b$, $E \rightarrow \eta_{s\bar{s}1}$, $\chi(3415) \rightarrow \omega_{\bar{c}c}$, P_o. There would be 17 η's and 17 ω's. Finally it was suggested that we use spectroscopic notation $_JP^C{}_IG$:

$\epsilon(1300) \rightarrow 0^{++}0^+(1300)$
$K(495) \rightarrow 0^- \; 1/2 \; (495)$
$D\,(1865) \rightarrow 0^- \; 1/2 \; (1865) \; c\bar{d}$

While spectroscopic notation is an excellent means of identifying particles and we include such information, the names we are discussing are really nicknames for rapid identification.

The conclusions are to be written by the reader, and hopefully they will be mailed to the Particle Data Group, which is anxious to learn your opinions. Our address is: Particle Data Group, 50-308, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA.

Appendix

Let me summarize some of the immediate reaction I obtained at this conference. Two individuals expressed reservations about the utility of any renaming proposal, and worried about confusion it might cause. The large majority of participants expressed strong support for the motivations and outline of the proposal. Like the letters we have received, there was no pattern to suggestions for modifications, nor was there a clear preference for any particular version of the proposal. I enjoyed the suggestion that the names of the particles should be sold to the highest bidder in order to finance the Superconducting Super Collider (SSC).

References

1. F. C. Porter et al. (Particle Data Group), LBL report no. LBL - 18834.
2. A. Hendry and D. Lichtenberg, Phys. Rev. D**12**, 275(1975) and Rep. Prog. Phys. **41**, 1707(1978).
3. N. Samios, in *Proceedings of Baryon 1980, The IVth International Conference on Baryon Resonances*, ed. by N. Isgur (University of Toronto, Toronto, 1980) p.309. 76SF00098 AC03 Aguilar al Baryon baryon BARYONS baryons Benitez CA Cahn CH Daps de ed Energia eqn Gidal Hendry Hernandez IIa IIb IIc Isgur IVth LBL Lederer Lichtenberg Lucien Md MeV Montanet PHY83 Phys Prog qroff Quigg Rev Rittenberg rnqvist Roos Samios SF SSC tbl Thun Trippe Wohl Wolfenstein

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720