Particle Zoo

Before the end of XIX century, atoms were thought to be indivisible. Then p, n, e were discovered, and all structure of chemical elements suddenly was explained by the existence of three elementary particles — beautiful! Then troubles began with β-decay

$$n \rightarrow p + e^- + \bar{\nu}_e$$
$$p \rightarrow n + e^+ + \nu_e$$

positron! positive twin of an electron or anti-electron

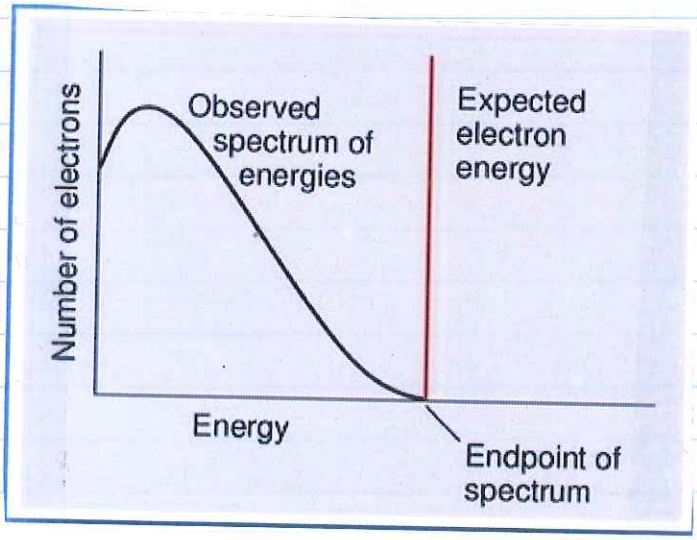
Moreover, the process seemed to violate energy conservation.

$n \rightarrow p + e^-$ $\quad m_n c^2 = m_p c^2 + m_e c^2 + Q$

since proton is so much heavier, pretty much all disintegration energy goes to the electron

$$K_e = \frac{m_p}{m_p + m_e} Q = 1.29\,\text{MeV}$$

So we'd expect all electrons from β-decay also to have energy $K_e = 1.29$ MeV → not so!

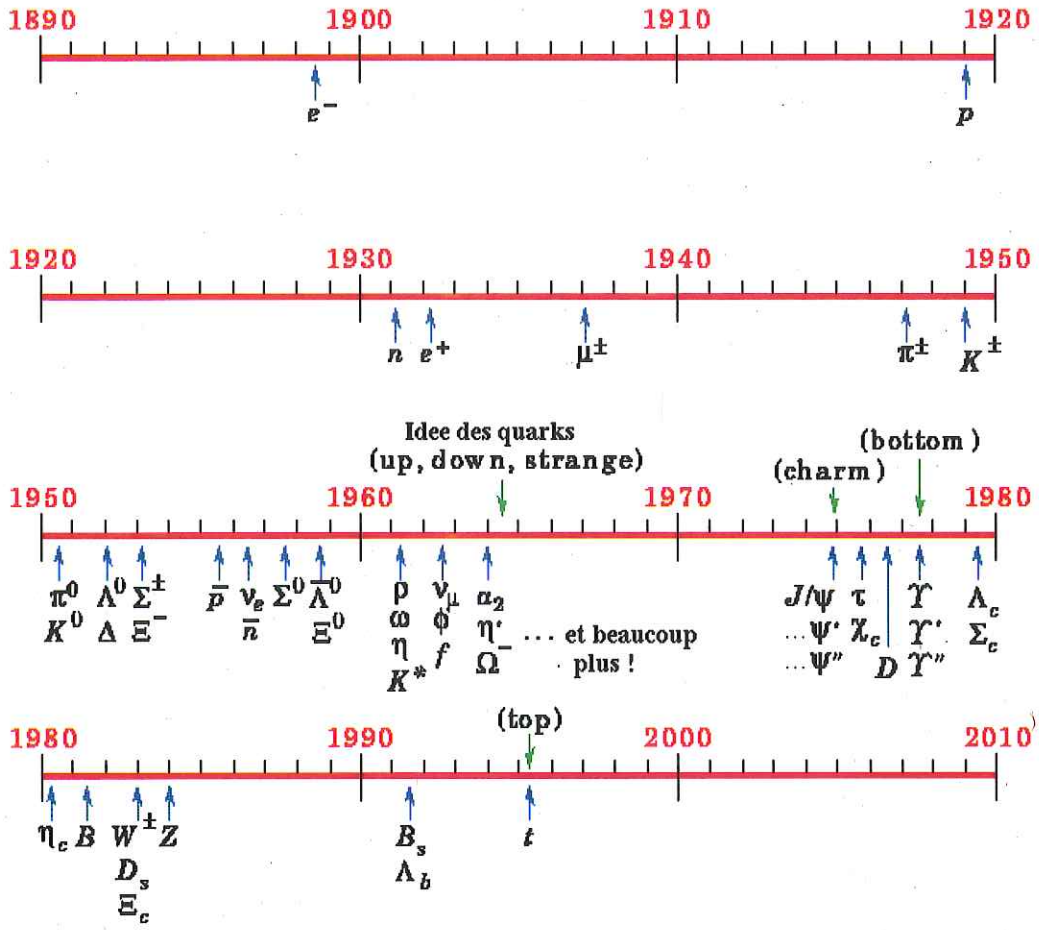


The second important new quantum number is strangeness.
It was found that some particles decay much slower than predicted by the strong interaction (which is strange), but instead by a weak force.
To add to the strangeness, such particles were always created ~~by~~ in pairs, but the products of decay were different.
So the scientists assumed that this "strangeness" is preserved in strong force, but not conserved in weak interactions.

Strangeness S 0 – normal particles
1 – strange particles
-1 – strange anti-particles.

Gell-Mann eight-fold way (Mathematical poetry)

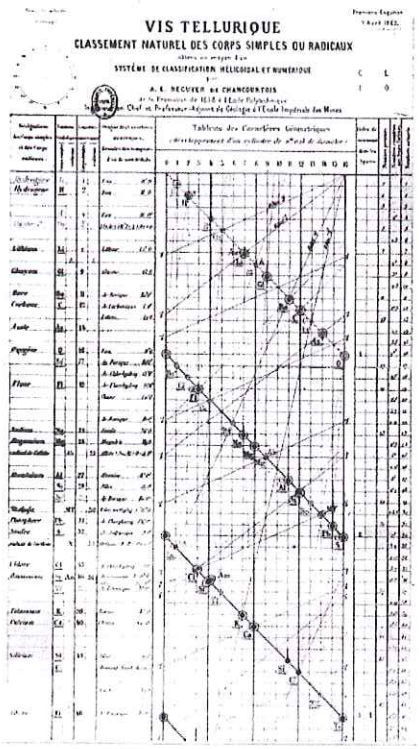
It is possible to group particles with some spin in symmetric structures in $I_3 S$ plane

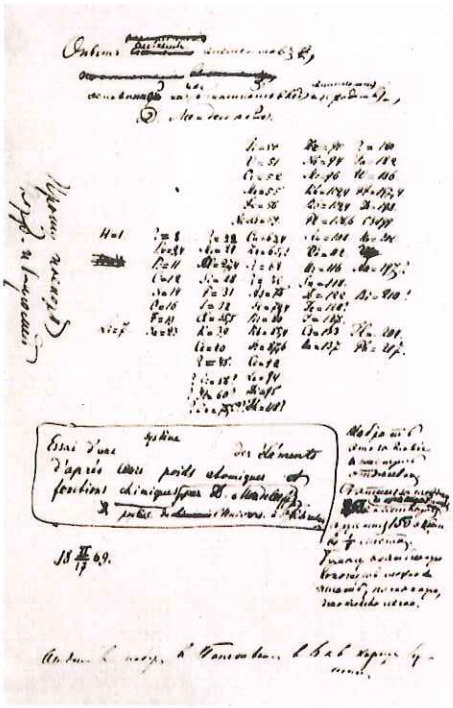

1890
1900
1910
1920
e⁻
p
1920
1930
1940
1950
n
e⁺
μ±
π±
K±
Idee des quarks
(up, down, strange)
(charm)
(bottom)
1950
1960
1970
1980
π⁰ Λ⁰ Σ±
K⁰ Δ Ξ⁻
p̄ νe Σ⁰ Λ̄⁰
n̄ Ξ⁰
ρ νμ α2
ω φ η'
η f Ω⁻
K*
... et beaucoup plus !
J/ψ τ Υ Λc
...ψ' χc Υ' Σc
...ψ'' D Υ''
1980
1990
2000
2010
(top)
ηc B W± Z
Ds
Ξc
Bs
Λb
t

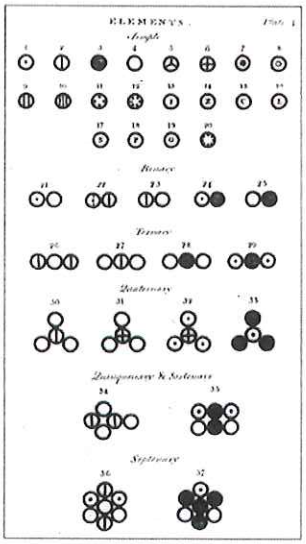
192 DES SUBSTANCES SIMPLES.

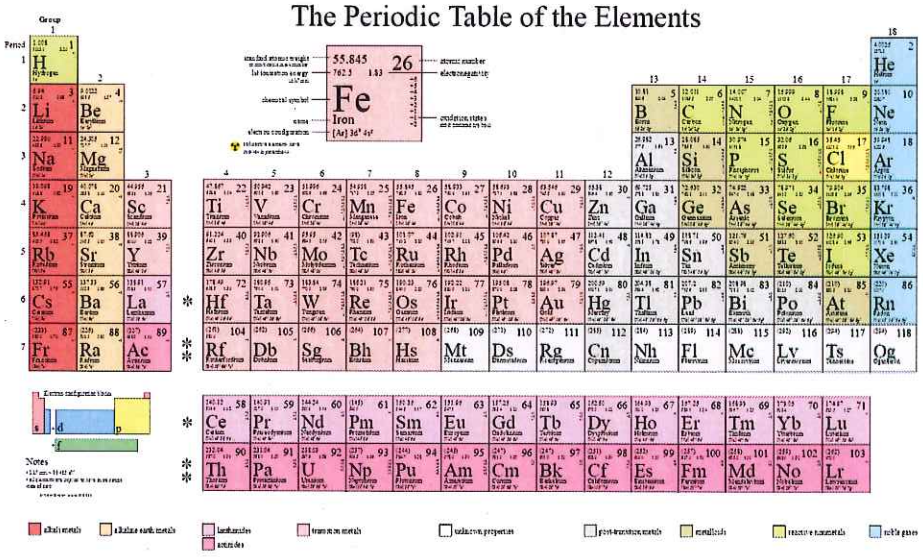
TABLEAU DES SUBSTANCES SIMPLES.

	Noms nouveaux.	Noms anciens correspondans.
Substances simples qui appartiennent aux trois règnes & qu'on peut regarder comme les élémens des corps.	Lumière	Lumière.
	Calorique	Chaleur. Principe de la chaleur. Fluide igné. Feu. Matière du feu & de la chaleur.
	Oxygène	Air déphlogistiqué. Air empiréal. Air vital. Base de l'air vital.
	Azote	Gaz phlogistiqué. Mofete. Base de la mofete.
	Hydrogène	Gaz inflammable. Base du gaz inflammable.
Substances simples non métalliques oxidables & acidifiables.	Soufre	Soufre.
	Phosphore	Phosphore.
	Carbone	Charbon pur.
	Radical muriatique	Inconnu.
	Radical fluorique	Inconnu.
	Radical boracique	Inconnu.
Substances simples métalliques oxidables & acidifiables.	Antimoine	Antimoine.
	Argent	Argent.
	Arsenic	Arsenic.
	Bismuth	Bismuth.
	Cobolt	Cobolt.
	Cuivre	Cuivre.
	Etain	Etain.
	Fer	Fer.
	Manganèse	Manganèse.
	Mercure	Mercure.
	Molybdène	Molybdène.
	Nickel	Nickel.
	Or	Or.
	Platine	Platine.
	Plomb	Plomb.
	Tungstène	Tungstène.
	Zinc	Zinc.
Substances simples salifiables terreuses.	Chaux	Terre calcaire, chaux.
	Magnésie	Magnésie, base du sel d'Epsom.
	Baryte	Barote, terre pesante.
	Alumine	Argile, terre de l'alun, base de l'alun.
	Silice	Terre siliceuse, terre vitrifiable.









Classifying particles

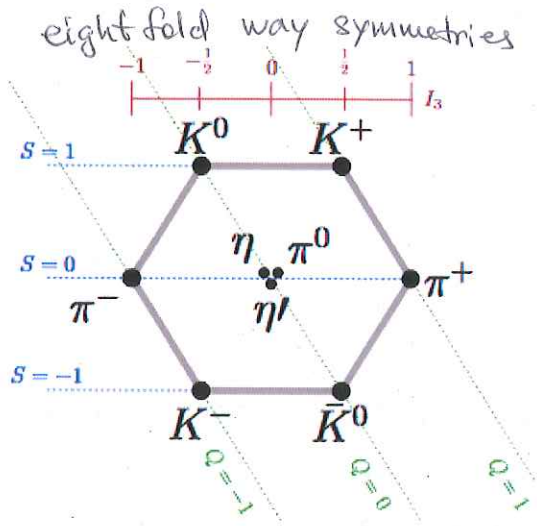
Electric charge is irrelevant for a strong or weak force. (although all particles have electric charge value, and spin value)

strong-force sensitive particles (hadrons)

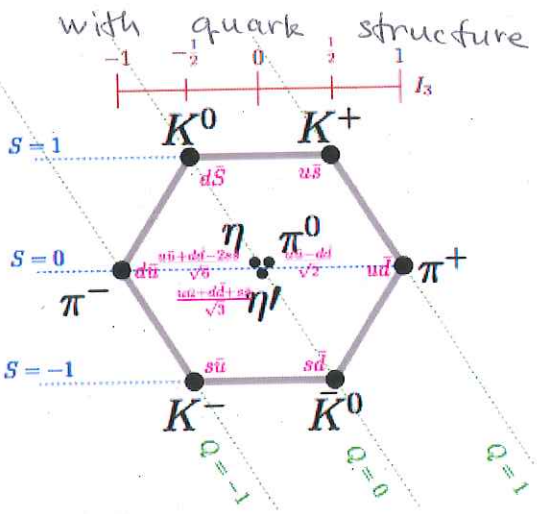
- baryons: half-integer spin; p, n; Σ, Δ, ...
- mesons: integer spin; pions, kaons,

some particles look suspiciously similar proton & neutron (same mass, same spin) this is almost like the two states of the same particle (like spin-up and spin-down electron, for example)
So, proton & neutron form a doublet with I_3 = isospin $1/2$

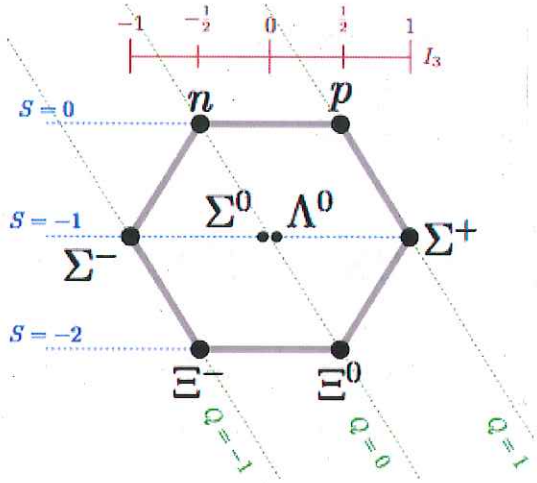
Similarly, three pions (π^+, π^- and π^0) are similar in mass, and their strong force interaction does not distinguish b/w them is triplet — isospin $I_3 = 1$
After sufficient number of particles is detected, an isospin value can be assign to all of them



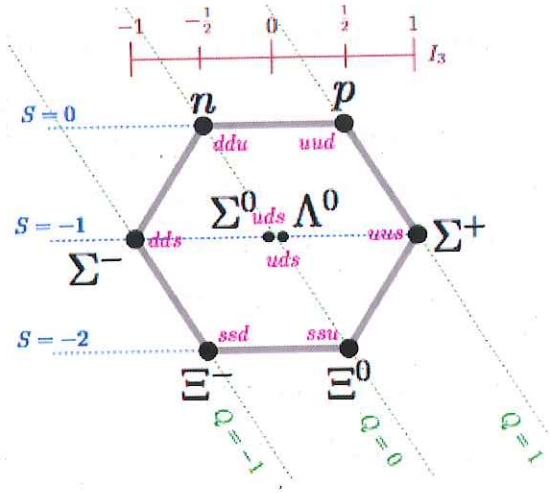
The spin 0 pseudoscalar meson nonet. (Illustration by the author.)



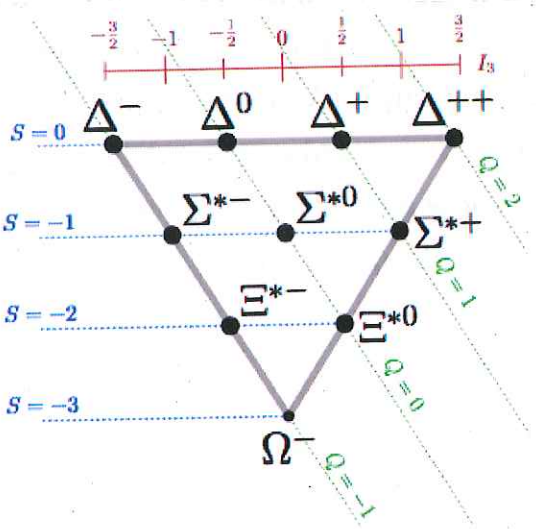
The spin 0 pseudoscalar meson nonet, with quark composition. (Illustration by the author.)



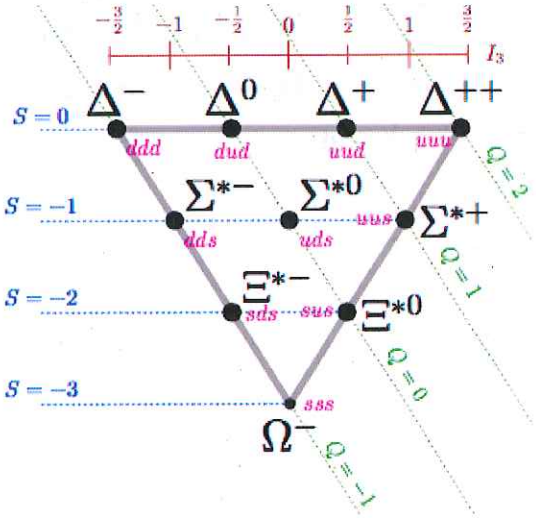
The spin 1/2 baryon octet. (Illustration by the author.)



The spin 1/2 baryon octet, with quark composition. (Illustration by the author.)



The spin 3/2 baryon decuplet. (Illustration by the author.)



The spin 3/2 baryon decuplet, with quark composition. (Illustration by the author.)

Gell-Mann and Zweig:

Triangular symmetry ought to be reflected in nature as three spin 1/2 fundamental particles, from which all hadrons (barions and mesons) are built!

Quark model

Three (back then) distinct flavors up (u), down (d), strange (s)

Quarks	electric charge	barionic charge	Strangeness charge	mass
u	$+2/3$	$+1/3$	0	1.7-3.3 MeV
d	$-1/3$	$+1/3$	0	4.1-5.8 Spin = 1/2 for all quarks
s	$-1/3$	$+1/3$	-1	101 MeV (much heavier)

Rules of quark model

Barion = 3 quarks (anti-barion = 3 anti-quark)

Meson = quark + antiquark

$p = duu$ [e-charge $2/3 + 2/3 - 1/3 = 1$]

$n = udd$ [e-charge $2/3 - 1/3 - 1/3 = 0$]

$\pi^+ = u\bar{d}$ [$2/3 - (-1/3) = 1$]

$\pi^0 = u\bar{u}$ or $d\bar{d}$

$K^+ = u\bar{s}$ $K^0 = d\bar{s}$; $K^- = \overline{K^+} = \bar{u}s$, $\overline{K^0} = \bar{d}s$

as a results of further studies, 3 more quarks were added

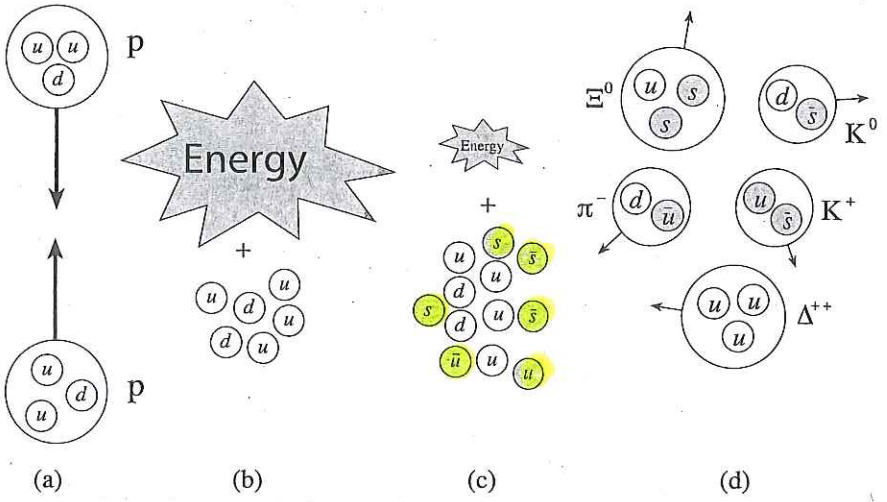
charmed quark (since the idea of having a pair for the strange quark was charming)

top (truth) (hardest to achieve!)

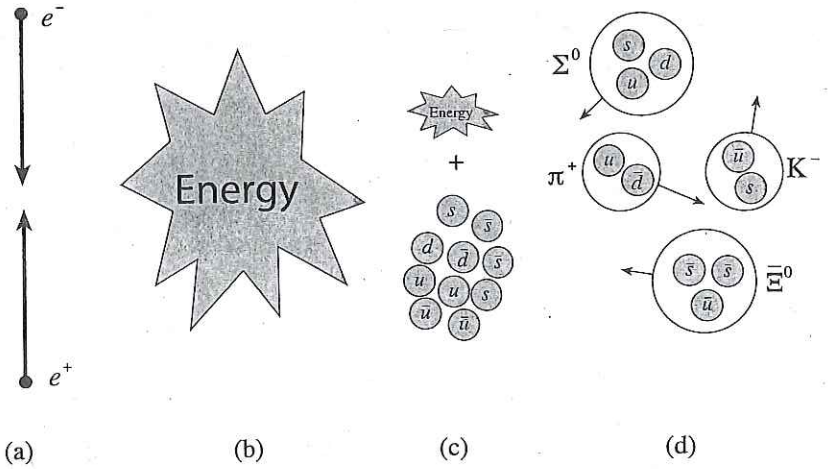
bottom (beauty)

Properties	Up (u)	Down (d)	Charm (c)	Strange (S)	Top (T)	Bottom (b)
Mass	350	350	1800	550	20.000	4500
Q-charge in unites of (e)	2/3	-1/3	2/3	-1/3	2/3	-1/3
B-Baryon number	1/3	1/3	1/3	1/3	1/3	1/3
C-charmness	0	0	+1	0	0	0
S-strangeness	0	0	0	-1	0	0
b-bottomness	0	0	0	0	0	-1
T-topness	0	0	0	0	+1	0
S-spin	1/2	1/2	1/2	1/2	1/2	1/2
I-isospin	1/2	1/2	0	0	0	0
I_z-isospin in z-dirction	1/2	-1/2	0	0	0	0
p-parity	+1	+1	+1	+1	+1	+1

LHC



ILC (future, in Japan)



James Joyce, Finnigans Wake

— *Three quarks for Muster Mark!*
Sure he hasn't got much of a bark
And sure any he has it's all beside the mark.
But O, Wreneagle Almighty, wouldn't un be a sky of a lark
To see that old buzzard whooping about for uns shirt in the dark
And he hunting round for uns speckled trousers around by Palmer-
stown Park?
Hohohoho, moulty Mark!
You're the rumniest old rooster ever flopped out of a Noah's ark
And you think you're cock of the wark.
Fowls, up! Trisiy's the spry young spark
That'll tread her and wed her and bed her and red her
Without ever winking the tail of a feather
And that's how that chap's going to make his money and mark!

Overhoved, shrillgleescreaming. That song sang seaswans. The winging ones. Seahawk, seagull, curlew and plover, kestrel and capercallzie. All the birds of the sea they trolled out rightbold when they smacked the big kuss of Trustan with Usolde.

And there they were too, when it was dark, whilest the wildcaps was circling, as slow their ship, the winds aslight, upborne the fates, the wardorse moved, by courtesy of Mr Deaubaleau Downbellow Kaempersally, listening in, as hard as they could, in Dubbeldorp, the donker, by the tourneyold of the wattarfalls, with their vuoxens and they kemin in so hattajocky (only a