1964:
Barnes et al. discover the $\Omega^-$ ($S = -3, M = 1686 \pm 12$ MeV) as predicted by the “eightfold way” with the mass as given by the Gell-Mann-Okubo mass formula ($M_{\Omega} = 3M_\Sigma - 2M_\Delta \sim 1683$ MeV).

Puzzles:
None of the known hadrons could be classified according to the fundamental representation of SU(3), i.e. the representation from which all other multiplets can be built: $I_{max} = 1/2, Y = -2/3, 1/3$.

Why do mesons (B=0) only appear as singlet and octet representations of the flavor-SU(3) and baryons (B=1) only as singlets, octets and decimets?
The flavor-SU(3) classification strongly hinted at the existence of a substructure of hadrons:

Gell-Mann and Zweig introduce the quark model: \( u, d, s \)

The quarks \( u, d, s \) form a triplet under flavour-SU(3) and are assumed to have the following internal quantum numbers:

<table>
<thead>
<tr>
<th></th>
<th>( I )</th>
<th>( I_3 )</th>
<th>( Y )</th>
<th>( S )</th>
<th>( B )</th>
<th>( Q = I_3 + Y/2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( u )</td>
<td>1/2</td>
<td>+1/2</td>
<td>+1/3</td>
<td>0</td>
<td>1/3</td>
<td>2/3</td>
</tr>
<tr>
<td>( d )</td>
<td>1/2</td>
<td>-1/2</td>
<td>+1/3</td>
<td>0</td>
<td>1/3</td>
<td>-1/3</td>
</tr>
<tr>
<td>( s )</td>
<td>0</td>
<td>0</td>
<td>-2/3</td>
<td>-1</td>
<td>1/3</td>
<td>-1/3</td>
</tr>
</tbody>
</table>

Hadrons are now understood as boundstates of two and three quarks:
mesons: \( q\bar{q} \), baryons: \( qqq \)

The product representation of a quark and anti-quark in terms of irreducible parts is \( 3 \times 3^* = 1 + 8 \) and for three quarks it is \( 3 \times 3 \times 3 = 1 + 8 + 8 + 10 \).
Puzzle:
The overall wavefunction of the $J^P = 3/2^+$ baryon resonance $\Delta^{++}$ with the three up-quarks being in the ground state is total symmetric
\[ \Delta^{++} \sim u(\uparrow)u(\uparrow)u(\uparrow)\Psi(x_1, x_2, x_3) \]
with the space part $\Psi(x_1, x_2, x_3)$ being total symmetric. But a total symmetric wavefunction for particles with spin $1/2$ contradicts the Pauli principle.

1964/65:
Greenberg, Han and Nambu solve this puzzle by increasing the degrees of freedom of the quarks. In the formulation of Gell-Mann (1972) and Fritzsch (1973) a new quark quantum number is introduced, color, so that each quark exists in three different colors: red, green, blue:

Baryons: \[ 1/\sqrt{6} \sum_{c_1, c_2, c_3} qf_{1,c_1} qf_{2,c_2} qf_{3,c_3} \epsilon_{c_1 c_2 c_3} \]
Mesons: \[ 1/\sqrt{3} \sum_{c_1, c_2} qf_{1,c_1} \bar{q}f_{2,c_2} \delta_{c_1 c_2} \]
with the total antisymmetric tensor $\epsilon_{123} = +1, \epsilon_{213} = -1 \ldots$