Glossary

Accuracy and completeness are sacrificed to the gods of simplicity and brevity.

α The electromagnetic coupling parameter.

α_s The strong coupling parameter.

Abelian group The mathematical expression of a symmetry in which two symmetry transformations give the same outcome irrespective of the order in which they are performed. The group $U(1)$ is Abelian.

action The sum over time of the difference between kinetic energy and potential energy.

AGS Alternating Gradient Synchrotron, a proton accelerator at Brookhaven National Laboratory, USA.

ALEPH One of the four detectors at LEP, the electron-positron collider at CERN, Switzerland.

AMY One of the four detectors at TRISTAN, an electron-positron collider at KEK.

anomalous magnetic moment The departure from the ideal point-particle value of a particle's magnetic moment.

antiparticle A partner to a particle, having the same mass but opposite electric charge. Positrons are the antiparticle partners of electrons; some particles such as the photon and the IT° are their own antiparticle.

asymptotic freedom The diminution of the color force between quarks as the distance between them is reduced.

axion A feebly interacting particle, now assumed to have a minute mass, introduced to resolve a symmetry problem in QCD. Never observed, it is also a candidate for the missing mass of the Universe.

B mesons Mesons containing a b quark.

barn A unit of area, equal to 10^{-28} m^2, used to describe scattering experiments.

baryon A heavy, strongly interacting matter particle composed of three quarks, for example the proton.

baryon number A quantity conserved in all interactions, equal to the number of baryons minus the number of antibaryons.

beam pipe In an accelerator, the innermost pipe containing the particle beam.

BFKL equation A mathematical expression allowing for the inclusion of many low-energy gluons, for example when considering the scattering of electrons off protons.

Big Bang The postulated creation of the Universe as a cataclysmic fireball followed by billions of years of cooling and expansion.

Bjorken sum rule Relates the difference in longitudinal spin content of protons and neutrons to weak interaction parameters.

boson A particle having zero or integer spin, for example a photon; many such particles can inhabit the same state at the same time.

bottom A quantum number associated with the bottom or b quark, which has a bottom value of -1; sometimes called the beauty quantum number.

bottomonium states A set of mesons comprising excited states of a bottom quark and bottom antiquark pair.

bremsstrahlung Photons emitted as a charged particle loses energy, or gluons emitted as a quark or antiquark) loses energy.

bubble chamber A type of particle detector in which particle tracks are revealed as trails of bubbles in a superheated liquid.

C The charge conjugation operation, which swaps a particle with its antiparticle. The C operation converts an electron into a positron, but leaves a photon a photon.

calorimeter An outer segment of a particle detector that measures the energy of particles emanating from an interaction.

Casimir effect A force serving to push together two conducting plates by virtue of fluctuations in the vacuum; a consequence of zero-point energy.

CDF Collider Detector Facility; one of two detectors on the Tevatron proton—antiproton collider.

CERN The European Laboratory for Particle Physics, near Geneva, Switzerland.

CESR Accelerator colliding electrons and positrons, Cornell, USA. channel One of several routes by which some process occurs.

charm A quantum number associated with the charm or c quark, which has a charm value of +1.

charmonium states A set of mesons comprising excited states of a charmed quark and charmed antiquark pair.

chiral perturbation theory Relative to conventional QCD calculations, a non-perturbative technique in which the chiral-symmetry-breaking portion of QCD is treated as a small perturbation to the chiral-symmetry-preserving part.

chiral restoration The recovery of chiral symmetry that is presumed to occur at high temperatures and densities.

chiral symmetry Symmetry that acts independently on left-handed and right-handed systems.

chromo-electric force The color force between two static color charges, the color analog of the electrostatic force between two static electric charges.

chromo-magnetic force The color force between two moving color charges, in particular spinning color charges; the color analog of magnetic forces between moving electric charges.

cloud chamber An old style of particle detector in which particle tracks emerge as "vapor trails" of droplets initiated by the passage of the particle through a vapor.

coherence A relationship between waves, in which two waves of the same frequency are said to be coherent if one always lags behind the other by a constant amount.

colliding beam experiments. Experiments in which one particle beam collides with another head-on. The low probability of collisions occurring is compensated by the much larger collision energy, relative to fixed-target experiments.

color The attribute of quarks and gluons that is the source of their strong interaction, much as electric charge is the source of the electrical interaction between charged particles; there are three distinct colors, red, green, and blue.

color coherence The destructive interference between successively emitted low-energy gluons, causing angular ordering of the emitted gluons and a suppression of particles between the quark and antiquark jets in a three-jet event.

color singlet A combination of colored entities, such as the three quarks of a proton, that has zero net overall color. Observable particles are color singlets.

condensate A state formed when many identical particles lock together in some way to form a lowest energy overall configuration. Quarks, monopoles, and Cooper pairs can all form condensates.

confinement A key postulate of QCD that says free quarks and gluons cannot exist, but must live in composite particles such as protons and neutrons for which the total colors blend to give a "white" particle, in technical terms a color singlet.

conservation laws Rules that describe quantities that remain unchanged during some process. Everyday examples are energy and momentum conservation. In particle physics, there are many more conservation laws, for example baryon number conservation and, for the strong interaction,

isospin conservation Conservation laws are related both to the conserved quantities used to describe and classify interactions, and to underlying symmetries of the interaction.

constituent quark mass The quark mass as it emerges from the quark model; the constituent mass of both up and down quarks is roughly a third of the proton mass.

Cooper pairs The conductors of electricity in a superconductor, comprising loose pairings of two electrons to create delocalized spin 1 particles.

coupling "constant" A dimensionless number expressing the strength of an interaction. Perturbation theory solutions are expressed as powers of the coupling constant. Frequently, the word parameter is more appropriate than constant.

covariance The property of a relationship between quantities in which that relationship remains unchanged even following some transformation, for example a Lorentz transformation, that acts on those quantities; also called form invariance.

CP symmetry The combined symmetries of particle-antiparticle inter-change symmetry, the C, and right- and left-hand coordinate interchange symmetry, the P. CP symmetry links left-handed neutrinos and right-handed antineutrinos.

CP violation The spoiling of CP symmetry, evident in K meson and B meson systems; implies a unique and absolute means of describing left and right, and perhaps explains the dominance of matter over antimatter in the Universe.

CPT symmetry The combined symmetries of particle-antiparticle interchange symmetry, the C, and right- and left-hand coordinate interchange symmetry, the P, and time-reversal symmetry, the T. All field theories obey CPT symmetry, which is necessary to preserve the exact correspondence between particles and antiparticles.

critical phenomena Phenomena characterized by the loss of distinction between two phases of matter.

critical point The conditions, for example temperature and pressure, specifying where two phases of a system merge and become indistinguishable from one another.

cross-section A characteristic area controlling the probability that two particles interact.

current quark mass The small quark mass values linked to the spoilage of symmetry of a massless strong interaction theory.

D mesons Mesons containing a charmed quark.

D0 One of two detectors on the Tevatron proton-antiproton collider.

dark matter Invisible material that is thought to contribute a large fraction of the total mass of the Universe.

decay rate The reciprocal of the average time an isolated particle lives before disintegrating.

deconfinement transition The jump from a state where quarks and gluons are confined to one where they are not confined, presumed to occur at high temperatures and densities.

deep inelastic scattering Scattering of an electron (or muon or neutrino) that probes the innermost components of the target nucleon.

DELPHI One of the four detectors at LEP, the electron-positron collider at CERN, Switzerland.

DESY German accelerator center, Hamburg.

deuterium A heavy isotope of hydrogen in which the nucleus, called the deuteron, comprises one proton and one neutron, in contrast to regular hydrogen in which the nucleus is a single proton.

DGLAP evolution equations Equations that describe the way in which structure functions depend on the wavelength of the probe used to measure them.

diffractive scattering Scattering in which one participant particle scatters elastically, retaining its identity, while the other is broken up.

dimensional regularization Isolation of the infinities due to closed loops of Feynman diagrams using a continuously varying dimension parameter.

direct photon A photon that interacts as a whole photon with a charged component of the target, without first disintegrating.

divergence An infinite result in a calculation, caused either by some quantity that increases without limit, or by dividing by some quantity that drops to zero.

DORIS Old electron-positron collider at DESY, Germany.

Drell-Yan mechanism The annihilation of a quark and antiquark pair, spawning an electron-positron pair or a pair comprising some other lepton and its antiparticle partner.

drift chamber Particle detector element for mapping particle tracks; relies on measuring ionization in a gas due to transiting charged particles.

dynamical quarks In lattice QCD, quarks that pop into existence from the vacuum, as distinct from valence quarks that are present at the start of the calculation.

effective quantum field theory A non-renormalizable quantum field theory applicable over a specific energy range.

elastic scattering Scattering in which particles "bounce" of one another, giving emerging particles identical to the colliding ones.

electron A stable, point-like, fundamental particle, the carrier of the basic unit of electric charge. Since electrons have spin +1/2 they are fermions; their mass is 0.511 MeV. The atomic nucleus is surrounded by orbiting electrons.

electronvolt A very small unit of energy.

electroweak theory The Glashow-Weinberg-Salam theory of weak force, according to which the weak interaction is mediated by W and Z bosons.

EMC European Muon Collaboration, a research group studying muon-nucleon scattering at CERN, Switzerland.

EMC effect The modification of the quark distributions within a free nucleon when that nucleon is instead part of a large nucleus.

exclusion principle The principle that no two electrons, or two of any other species of fermions, may occupy the exact same quantum state. Also known as the Pauli exclusion principle.

exclusive process A scattering process in which all the final-state particles are detected and measured.

Faddeev-Popov ghost *See* ghost

families The groupings of fundamental "matter" particles, or fermions, into three matching sets, the first of which includes the up and down quark, the electron and its neutrino.

fermion A particle of half-integer spin, such as an electron, proton, or quark. Fermions obey the exclusion principle.

Feynman diagram Diagrammatic representations of a portion of an approximate mathematical calculation of some particle physics process.

field A quantity or influence spread over some region, rather than being concentrated at a single point.

field theory Any theory in which the quantities of interest are represented as fields, as opposed to points. In a quantum field theory, a field is an assemblage of packets of different energies.

fixed-target experiments Those in which an incoming particle beam is directed onto a stationary target, for example a block of iron, and the resulting debris is projected into a cone following the direction of the incoming beam.

flavor The type attribute of a quark. The six flavors are up, down, strange, charm, bottom, and top.

four-momentum An extension of the usual momentum of mechanics ("three-momentum") to include an extra, fourth portion, the energy, on an essentially equally footing.

four-vector A group of four numbers specifying a quantity, for example an interval in space-time. The magnitude of a four-vector is unchanged by a Lorentz transformation.

fragmentation A process by which a quark or gluon becomes a jet of strongly interacting observable particles.

fragmentation function The probability that a quark or gluon fragments to give a meson having a momentum fraction equal to the meson momentum divided by the original quark or gluon momentum.

gauge field A field introduced in order to preserve local symmetry. In quantum theory these are spin 1 bosons that carry force; the photon, W and Z particles, and gluons are all gauge fields.

gauge symmetry Symmetry under space-time dependent changes in the phase of the field.

gauge theory A quantum theory in which the interactions are determined by local symmetry properties.

general relativity Einstein's theory of gravity, relating the force of gravity to the geometry of space-time.

GeV A unit of energy, the giga electronvolt, equal to a thousand million electronvolts.

ghost A contribution to certain Feynman diagrams; ghosts correspond to unphysical particles required to preserve probability conservation in non-Abelian gauge theories.

global transformation A transformation that is the same for every space-time point.

glueball A neutral meson composed entirely of gluons.

gluon According to QCD, gluons carry the strong force. Gluons are fundamental, massless, electrically neutral, spin 1 bosons. They carry eight different color assignments. On Feynman diagrams they are conventionally represented by corkscrew curves.

Goldstone bosons Massless particles that owe their existence to spontaneous symmetry breaking.

Green's function In field theory, an amplitude for a physical process, the summation of a set of Feynman diagrams.

ground state The lowest energy state of a quantum mechanical system.

group A mathematical expression of symmetry. Formally, in mathematics a group is a set whose elements obey four particular rules.

H1 A detector at the HERA electron-proton collider, DESY, Germany.

hadron A strongly interacting particle. Hadrons containing three quarks are called baryons. Hadrons containing quark-antiquark pairs are called mesons.

handed A distinction between left-handed and right-handed. A conventional wood screw is termed right-handed because it moves forward into the wood when turned clockwise.

hard interaction One in which the momentum transfer is large.

HERA Electron-proton collider at DESY, Germany

Higgs particle A proposed but as yet unobserved particle that plays a key role in symmetry breaking and the origin of particle masses in the electroweak theory of the weak force.

higher-twist effects Contributions to particle interactions arising from correlations between particles that become significant at low-energy regimes. They are non-perturbative effects that can only be estimated.

inclusive process One in which only a single particle of those produced is identified and measured. The remaining event products are ignored.

inelastic scattering Scattering in which energy from colliding particles is used to create new ones, so the particles leaving a collision do not match exactly those entering.

infrared divergence A divergence associated with an energy that falls to zero.

instanton A transient, massless, gluon "knot," topological in origin, capable of flipping the handedness of a quark.

integrated luminosity The accumulation over time of the brightness of the beam(s) in an accelerator.

invariant A quantity unchanged by a transformation.

invariant mass The useful energy available for particle creation in some collision, having the same value for all observers, i.e., a Lorentz invariant. Denoted $\sqrt{s}$.

ISR Intersecting Storage Rings; a proton-proton collider at CERN, Switzerland, that ran from 1971 to 1984.

jet A directed, conical shower containing strongly interacting particles.

L3 One of the four detectors at LEP, the electron-positron collider at CERN, Switzerland.

Lambda (Λ) parameter A numerical constant, determined from experiment, linked to the size of the blob of space - roughly the size of a proton - over which QCD acts. The scale parameter has a value of about 200 MeV.

LEAR Low Energy Antiproton Ring, CERN, Switzerland.

LEP Electron-positron collider at CERN, Switzerland.

lepton Matter particles, such as electrons and muons, that do not experience the strong force.

lepton number A quantity conserved in all interactions, equal to the number of leptons minus the number of antileptons. Lepton numbers for electrons, muons, and taus are conserved independently.

LHC Large Hadron Collider at CERN, Switzerland.

Lie group A symmetry group corresponding to a continuous, smooth transformation, for example a rotation.

linac A linear accelerator with electrodes arranged in a straight line (hence linear) so that accelerating particles effectively surf an electromagnetic wave the length of the machine.

local transformation A transformation that is different for every point in space and time.

luminosity Brightness of the beam(s) in an accelerator.

magnetic moment A measure of a magnet's propensity to turn when subjected to an external magnetic field.

magnon Massless quantum particle associated with magnetization in magnetic materials.

master equation The master equation of QCD is an energy equation for quarks, gluons, and the color-based interactions between them. It is fed into the Feynman path integral in order to generate Feynman diagrams. Formally, and for people who know about these things, the master equation is a Lagrangian density.

matter wave The quantum wave associated with matter "particles" such as electrons.

Maxwell's equations The equations of electricity and magnetism due to James Clerk Maxwell.

mean life The average time an isolated particle exists before disintegrating. It is the reciprocal of the decay rate, and is proportional to the half-life, the time corresponding to a 50% probability of decay. The half-life is about 70% of the mean life.

meson A strongly interacting particle comprising a quark and an anti-quark, for example the pion.

Meissner effect In a superconductor, the expulsion of a magnetic field from the interior of the superconducting material.

MeV A unit of energy, equal to a million electronvolts. Particle masses are given in MeV. For example, the proton has a mass of 938.3 MeV.

momentum transfer squared The (negative of the) invariant mass of the virtual particle that mediates an interaction, denoted Q^2. For example, for an electron scattering from protons, Q^2 refers to the virtual photon mediating the scattering. High values of this quantity correspond to a short-wavelength probe able to see finer details.

monopole Literally, a single pole. A magnetic monopole is a lone north or south magnetic pole, though these do not occur in nature. A monopole in QCD, for example in the dual-superconductor model of confinement, is a lone chromo-magnetic field pole.

multiplet A collection of particles related to one another through some symmetry scheme.

muon An electrically charged elementary particle of mass 105.7 MeV, created for example in the weak decay of a pion, and usually decaying into an electron.

naive parton model The basic version of the parton model, in which point-like partons each simply carry a fraction of the parent nucleon momentum, and Bjorken scaling is satisfied.

neutrino A low-mass, weakly interacting matter particle having no electric charge, and no role in the strong force. There are three types of neutrino.

neutron A strongly interacting, neutral particle made up of udd quarks. The atomic nucleus is made up of neutrons and protons.

non-Abelian group The mathematical expression of a symmetry in which two symmetry transformations give different outcomes depending on the order in which they are performed. Both *SU*(2) and *SU*(3) are non-Abelian groups.

non-perturbative Describes some property or process that cannot be analyzed using the approximation technique called perturbation theory. The non-perturbative regime in QCD is the low-energy, long-distance regime encountered, for example, in the binding together of quarks to form protons.

nucleon A collective term meaning neutron and proton.

OPAL One of the four detectors at LEP, the electron—positron collider at CERN, Switzerland.

ORE *See* operator product expansion.

operator product expansion Expresses the short-distance behavior of some non-perturbative process in terms of non-perturbative background features whose relative contributions are calculable in perturbation theory.

order (of a perturbation series) The power of the coupling parameter in the expression for the amplitude; power one is first order, power two is second order, etc.

P Parity

pair production In QED, the process in which a high-energy photon is destroyed as an electron-positron pair is created.

parity The mathematical version of creating a mirror image. Under the parity operation, a left-handed particle becomes a right-handed particle, and vice versa.

Particle Data Group An international team of particle physics researchers who co-ordinate, maintain, and update the Review of Particle Properties, the ultimate listing of particle properties and other key particle physics information (see http://pdg.lbl.gov/).

parton model A model of the nucleon in which it is viewed as composed of simple scattering centers called partons, identified with quarks and gluons. The "QCD-improved" parton model, as opposed to the naive parton model, caters for interactions between partons, and they no longer appear strictly point-like scatters having a simple fraction of the parent nucleon's momentum.

partons Scattering centers in the nucleon identified with quarks, anti-quarks, and gluons.

path integral Amplitude for the transition between quantum states expressed as a sum over all possible paths linking those states.

PEP Electron-positron collider at SLAC, USA.

perturbation theory A mathematical technique in which an approximate answer to an otherwise intractable problem is expressed as a sequence of successively smaller terms.

PETRA Electron-positron collider at DESY, Germany.

phase 1) A measure of a wave's progress relative to some origin. 2) The physical state of some substance, for example the liquid and steam phases of water, or the magnetized and unmagnified phases of iron.

phase stability The preservation of the relative timing between relativistic, accelerating particles, and the voltage doing the accelerating.

phase transition The change from one system phase to another, for example when water boils to give steam, or steam condenses into water.

phonon A packet, or quantum, of vibrational energy in a solid.

photomultiplier tube A detection device that turns tiny flashes of light into electrical pulses.

photon A "particle" of light, in other words a quantum of electromagnetic energy.

photoproduction Scattering with real or nearly real photons.

picobarn A unit of cross-section. One picobarn is 10^{-12} barns, or 10^{-40} m^2.

pion (or IT meson) A type of meson composed of up and down quarks and antiquarks, the carrier of the strong force binding protons and neutrons into the atomic nucleus.

PLUTO One of the four detectors on the PETRA electron-positron collider at DESY, Germany.

polarization The orientation of a particle's spin relative to its direction of motion. In right-hand polarized light, for example, the photon spin lies along the direction of the photon's flight. In transverse polarization, the particle's spin is oriented at right-angles to its flight path.

Pomeron An exchange (pseudo) particle mediating certain high-energy strong interactions. Composed mainly of gluons.

positron The antiparticle partner of the electron, having a positive electric charge.

positronium A short-lived "atom" made from a positron and an electron.

potential Ordinarily, the energy made available as a result of a change in the configuration of a system involving forces. The change in potential with distance is the strength of the relevant force field. Potentials become force-carrying quanta in quantum field theory.

principle of least action The rule that a mechanical system behaves in such a way that its action assumes the smallest possible value.

propagator The probability amplitude for a particle to propagate from one point to another.

proton A strongly interacting, positively charged particle made up of uud quarks. Hydrogen nuclei are protons. The atomic nucleus is made up of protons and neutrons.

pseudo-Goldstone bosons Low-mass particles, for example pions, that owe their origin to the spontaneous breaking of a symmetry that is not quite exact.

Q^2 See momentum transfer squared.

QCD Quantum chromodynamics, the theory of the strong force.

QCD sum rules Approximate, non-perturbative constraints on hadron parameters.

QCD vacuum The state of lowest energy of QCD.

quantum field theory The most evolved form of quantum theory, in which both matter and forces are described in terms of fields that are sums over quantum waves. Quantum field theory naturally accommodates particle creation and destruction.

quantum number Simple numbers or vectors that label and identify a quantum state and the results of measurements performed on that state. Conservation laws are expressed in terms of quantum numbers.

quark The fundamental strongly interacting particle, and carrier of color charge. In addition, quarks carry electric charge, and participate in electroweak interactions. There are six types, or flavors, of quark: up (u), down (d), strange (s), charmed (c), bottom (b), and top (t).

quark condensate A sea of quark-antiquark pairs, populating the vacuum, that forms the backdrop for strong interactions.

quark-gluon plasma A "gas" of free quarks and gluons.

quarkonium A meson comprising a heavy quark-antiquark pair. The plural is quarkonia.

radiative corrections In the calculation of the probability of some process occurring, radiative corrections are modifications arising from the emission of additional particles, for example low-energy photons in an electromagnetic process.

Regge theory The expression of strong interaction scattering in terms of the exchange of families of mesons.

regularization Mathematical procedure for isolating infinities. renormalization A program for extracting the physical content of a quantum field theory otherwise prone to giving infinite and therefore meaningless answers.

renormalization group A set of mathematical transformations that revises the parameters of a theory whilst leaving unchanged the interesting physical features.

resolved photon A photon that interacts in terms of the quarks and gluons associated with it. Loosely, a fragmented photon.

resonance An unstable particle that decays very quickly via the strong interaction into other strongly interacting particles.

$\sqrt{s}$ *See* invariant mass.

scale invariance Invariance under a change in the length of the ruler used to measure the system.

scale parameter *See* lambda parameter.

scattering The interaction of a beam of particles or radiation with some target, typically involving a redirection of at least some of the beam.

scintillator A material, used in particle detectors, that produces tiny flashes of light in response to a transiting particle.

signature Output from a particle scattering experiment that signals a particular process of interest.

silicon microstrip detector The basic element of a silicon vertex detector, relying on stripes of one semiconductor set in another to locate passing charged particles.

silicon vertex detector The inner layer of most particle detectors, relying on silicon technology to locate forks in particle tracks occurring very close to the original interaction point.

singlet A "family" comprising just a single member, built from component states whose characteristic of interest is combined in a particular way to give a zero value for the singlet. For example, a neutral atom is a charge singlet, an isospin singlet state such as the A has zero isospin, and observable strongly interacting particles are color singlets, meaning they have no net color yet are composed of colored quarks.

SLAG Stanford Linear Accelerator Center in Stanford, California.

Slavnov-Taylor identities Mathematical relationships between amplitudes in non-Abelian gauge theory; generalized Ward identities.

SLC Stanford Linear Collider, Stanford, California.

SMC Spin Muon Collaboration, an experimental group at CERN, Switzer-land.

soft interaction One in which the momentum transfer is small.

soliton A kind of isolated wave that does not spread or fade away.

SPEAR Electron-positron collider at SLAG, USA.

special relativity The mechanics applicable to objects traveling at speeds close to that of light.

spin An attribute of elementary particles that has parallels with the spin of everyday objects such as spinning tops. The spin of elementary particles can only assume specific values. Particles having whole-number spin (in units of h) are called bosons, those having half-number spins are called fermions.

spontaneous symmetry breaking The symmetry reduction that occurs when the lowest energy state has less symmetry than the relevant interaction.

Sp$\overline{\text{p}}$S Proton-antiproton collider at CERN, Switzerland.

SPS Super Proton Synchrotron at CERN, Switzerland.

staggered quarks In lattice QCD, the quarks resulting from a technical trick for removing accidental, unwanted replica quarks by distributing quark information across several lattice sites.

Standard Model The electroweak theory of the weak force in combination with the QCD theory of the strong force, applied to the familiar fundamental particles.

stochastic cooling The squeezing of a charged particle beam, especially antiprotons, to reduce spreading and create a well-defined beam suitable for subsequent accelerating.

storage ring A particle accelerator in which the beam follows the same roughly circular path many times, especially when the number of particles is being increased, or the beam is being saved for later use.

strangeness An attribute of strange particles, derived from the presence of a strange quark or antiquark. A strange quark has strangeness -1.

strong CP problem How to explain the small size of the parameter controlling the contribution of the instanton-generating term in QCD.

structure functions Momentum distributions of the nucleon's constituents.

sum rule A relationship between, or value ascribed to, momentum-summed quark or gluon distributions within the nucleon.

supersymmetry A symmetry linking particles having integer spin with those having half-integer spin. Though experimenters have so far not found evidence of supersymmetry, theories exploiting it have created great excitement amongst theorists.

synchrotron A particle accelerator in which the frequency of the accelerating pulses, and the strength of the bending magnetic field, are increased in a synchronized way so as to keep the accelerating particles on a circular path.

tagging The use of a some feature in collision debris as a signal of a particular process.

Tevatron Proton-antiproton collider at Fermilab, USA.

theta-vacuum The purported true vacuum of QCD, a blend of topologically distinct vacuum states.

TOPAZ One of the four detectors at TRISTAN, an electron—positron collider at KEK.

topological A property that describes gross features that are independent of geometry. American footballs and soccer balls are topologically the same (both are balls) but geometrically different (only one is a regular sphere).

trigger In a particle detector, the decision-making system for deciding whether to ignore or record an event.

twist *See* higher-twist effects.

U(1) **problem** The problem of reconciling an apparent symmetry of QCD (a *U*(1) symmetry) with the absence of particles such as proton partners implied by that symmetry.

unitarity The conservation of total probability in a collision process.

unitary A term used to describe transformations of particle families that preserve the overall particle content, analogous to the way that the rotation of a clock arm preserves the length of the arm.

universality The equality, irrespective of color and flavor, of the basic coupling strength between a quark and a gluon.

vacuum In an everyday sense, the nothing that remains when, for example, the air is pumped out of a sealed box. In quantum field theory, it is the state of lowest energy.

vacuum polarization The contribution to the energy of a particle such as a photon arising from the way it disturbs the vacuum around it.

valence quarks Those quarks that between them carry the quantum numbers that label their parent particle.

W particle Alternatively called the W boson, the heavy, electrically charged carrier of the weak force.

Ward identity Relationship between amplitudes that is useful for proving renormalization in quantum field theory. Sometimes called Ward-Takahashi identities or, in the non-Abelian case, Slavnov-Taylor identities.

Ward-Takahashi identities Generalized Ward identities.

Weinberg-Salam theory An alternative name for the electroweak theory.

width A measure of a particle's propensity to decay; the inverse of its lifetime. A narrow width corresponds to a long-lived particle.

Wilson quarks In lattice gauge theory, quarks having broken chiral symmetry, whose accidental, unwanted replicas have been spirited away by addition of the extra "Wilson term" to the lattice master equation.

x The fraction of a parent nucleon's momentum carried by a quark or gluon within.

Z particle Alternatively called the Z boson, the heavy, electrically neutral carrier of the weak force.

zero-point energy The residual minimum energy of a quantum state below which the system cannot go.

ZEUS A detector at the HERA electron—proton collider, DESY, Germany.