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Epistemological and Historical Implications for Elementary Particle Theories

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The epistemological credo of Einstein is further developed and specified in greater detail for practical applications. The results are applied to quasi-historical creation processes of established physical theories and to current theories for elementary particles. The outcome of these applications is then considered from epistemological viewpoints. Reasons underlying the basic difficulties of the current main stream particle theory, the standard model, are given. The steps in the creation of an alternative approach, the scalar strong interaction hadron theory, are delineated.

KEY WORDS: epistemology; Einstein's cred; elementary particle theories.

1. INTRODUCTION

The current main stream elementary particle theory is the standard model (SM) (Particle Data Group, 2004; Wilczek, 2005) which includes quantum chromodynamics (QCD) and the electro-weak interaction model (EWM). Despite the claim that QCD's predictions agree with many accurate experiments (Wilczek, 2005), QCD cannot account for low energy hadronic data, such as those given by the PDG (2004). In spite of the claim that EWM has been "wonderfully successful" (Wilczek, 2005), the Higgs boson, on which EWM hinges, has not been seen.

In view of these difficulties, an alternative to low energy QCD and EWM, the scalar strong interaction hadron theory (SSI) has been proposed (Hoh, 1993, 1994, 1996, 1999, 2005). This theory naturally accounts for many basic low energy hadronic phenomena that cannot be accounted for by QCD and EWM. The approach of SSI however drastically differs from that of SM and appears to be unfamiliar to most physicists.

To clarify this situation, therefore, EWM, QCD and SSI will be examined from two basic points of view. One of them is provided by epistemology or theory of knowledge, which in earlier centuries has been the main branch of philosophy

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but is presently much less dominant. Another one is given by the history of the creation of the established physical theories.

The epistemologies of interest are sketched in Appendix A. The teachings of these are generally accepted and are, is short, the common knowledge that theory needs be tested against experiment. But how this is practiced varies over a wide range of rigor. Allowing epistemology to bear upon the creation of physical theories will sharpen this practice. As the early Wittgenstein expressed: “The object of philosophy is the logical clarification of thoughts. Philosophy is not a theory but an activity. A philosophical work consists essentially of elucidations. The result of philosophy is not a number of philosophical propositions, but to make propositions clear.”

In Section 2, Einstein’s epistemological belief is further developed and specified in greater detail for practical applications. The results are then applied to creation processes of established physical theories from historical points of view in Section 3. In Section 4, the same procedure is carried out for EWM, QCD and SSI. The results of these studies are then discussed from epistemological viewpoints in Section 5. Section 6 gives the main conclusion of the present investigations. For reference, the epistemologies of interst are sketched in Appendix A. Appendix B presents difficulties of QCD. In Appendix C, the steps leading to SSI are given making use of Sections 2–3.

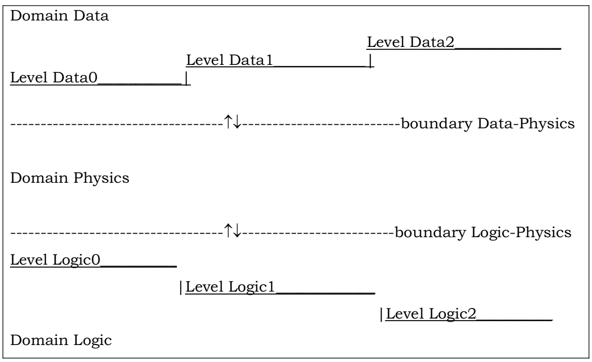

Fig. 1. It shows the three domains separated by two boundaries. The ↑↓ signs indicate that the contents in domains Data and Logic can be moved across the boundaries Data-Physics and Logic-Physics, respectively, into domain Physics and be brought back from it. Roughly speaking, the vertical distance between two levels indicates the distance between measurement and basic theory. The horisontal axis is some measure of time since renaissance. The left, middle and right parts of this figure are further considered in Sections 5.2–5.4 below.

2. FURTHER DEVELOPMENT OF EINSTEIN'S EXPOSITION

For the present investigations, the epistemologies mentioned in Appendix A need be specified in greater detail. Closest to the present application is Einstein's exposition in Section A3, which will be the starting point. To obtain practical rules for application, the ideas of Section A3 are extended and the results are represented in Fig. 1 below. His statements Ea in Section A3, which is equivalent to LPb in Section A2, is expanded to *domain Data* and Eb in Section A3, which is equivalent to LPa in Section A2, to *domain Logic*. His *connection* between Ea and Eb is expanded to an intervening *domain Physics*. These domains are set up in order to avoid possible mix-up of mathematical and physical concepts.

2.1. Domain Data

It consists of several levels Data0, Data1, Data2, ... The highest level contains raw experimental data, which by a series of treatments, which can for instance include Monte-Carlo calculations, are converted to quantities on lower levels and finally to the lowest level Data0. This level contains data in form of quantities that can be identified with corresponding quantities on level Logic0 in Section 2.2 below when brought into domain Physics. Algebraical combinations of such quantities are also on this level. Examples of the content of level Data0 are coordinates of a particle, temperature of a substance, magnetic field, electric current density, mass and decay time of a hadron, and in general data given by PDG (2004).

2.2. Domain Logic

It contains only logic and pure mathematics. Since Newton, such logical or *mathematical structures* have been differential equations for all known and established basic physical disciplines. For the sake of clarity, all symbols in domain Logic are attached by a prime $'$ which denotes that these symbols are mathematical quantities. The definitions, statements, propositions, and equations need only be self-consistent and obey conventions of logic, but are otherwise free from any restraint. They are exact but have no physical meaning and belong to LPa in Section A2 and Eb in Section A3 below. This domain presently consists of three levels, Logic0, Logic1 and Logic2.

Level Logic0 contains mathematical structures (differential equations) whose variables, or some quantities formed algebraically from them, when brought into domain Physics, can all be associated with and tested against the corresponding data quantities from level Data0. Examples are Newton's equations, thermodynamical relations and Ampére's law which becomes on this level

$$\nabla' \times \underline{B}'(\underline{x}') = \underline{j}'(\bar{x}') \tag{1}$$

This mathematical structure states that a vector field $\underline{j'}$ (not electric current density here) is defined as the curl of another vector field $\underline{B'}$ in a flat three dimensional space $\underline{x'}$.

Level Logic1 is more abstract. The mathematical structures (differential equations) therein will now be the source of the physics. Here, some *hidden dependent variables* which, after crossing the boundary Logic-Physics, have no corresponding quantities from level Data0 to identify with and compare to. Examples of such variables are the Schrödinger wave function ψ' and the metric tensor $g'_{\mu\nu}$ in general relativity. By mathematical manipulations the content on this level can be converted to that on level Logic0.

Level Logic2 is still more abstract. The mathematical structures (differential equations) therein will now be the source of the physics. However, in addition to hidden dependent variables, there are also some *hidden independent variables* and functions of them which, after crossing the boundary Logic-Physics, have no corresponding quantites from level Data0 to identify with and compare to. Examples of such variables are the relative space time between two quarks and coordinates in flavor space in SSI (see Appendix C). By mathematical manipulations, the content on level Logic2 can be converted to that on level Logic1 and, if necessary, subsequently to level Logic0.

2.3. Domain Physics

The contents or data on level Data0 are temporarily be brought across the boundary Data-Physics into domain Physics in Fig. 1. Simultaneously, a *mathematical structure* on level Logic0 is also temporarily carried across the boundary Logic-Physics and thereby loses the primes $'$ attached to the symbols therein and becomes a *theory* in domain Physics. The mathematical symbols in this theory are now intuitively assigned to various physical quantities. The theory has now physical meaning but is no longer exact. It is then worked out and tested against the corresponding data quantities in this domain. If the test is successful, the theory can be, but does not have to be, "right" (see Section A4). If there is disagreement or conflict, the theory in domain Physics and hence also the corresponding mathematical structure in domain Logic need be changed and more experiments may be called for. The contents in domain Physics are then brought across the boundaries Data-Physics and Logic-Physics back to levels Data0 and Logic0, respectively.

It is also possible to bring the mathematical structures on levels Logic1 and Logic2 directly arosss the boundary Logic-Physics into domain Physics to becomes physical theories, which can then be reduced to theories corresponding to those on level Logic0. This reduction was done in domain Logic in Section 2.2. These both ways of reduction are equivalent but the latter is simpler conceptually because one has only to follow the rules of logic and can leave physics aside in the meantime.

2.4. Development of Physical Theories

The history of the development of physical theories shows that the creation of a new theory can be considered to proceed in the following stages in terms of activities in the three domains of Sections 2.1–2.3.

Stage I: *Recent data.* This stage takes place in domain Data in which some new or recent data become available.

Stage II: *Conflict.* This stage takes place in domain Physics. The *Recent data* are brought across the boundary Data-Physics into domain Physics. Simultaneously, the associated *existing mathematical strutcure* in domain Logic, preferably reduced to level Logic0, is also carried over the boundary Logic-Physics into domain Physics to become the *existing theory*, which is then tested against the *Recent data*. A *Conflict* between the existing theory and the recent data arises. The existing theory is then returned into domain Logic to resume its role as the existing mathematical strutcure.

Stage III: *Leap.* This stage takes place in domain Logic. The *Recent data* in domain Physics in Stage II are taken across the boundary Logic-Physics to become a *recent mathematical requirement* in domain Logic. The *Conflict* in domain Physics becomes an *Inconsistency* in domain Logic between this recent mathematical requirement and the existing mathematical strutcure. A *Leap* or a change is then introduced into the existing mathematical strutcure to obtain a modified or *new mathematical strutcure* consistent with logical rules. This new mathematical strutcure may now be consistent with the recent mathematical requirement.

Stage IV: *Hypothesis-Theory.* The *Leap* made in domain Logic is brought across the boundary Logic-Physics to become a physical *Hypothesis* in domain Physics. The *new mathematical structure* becomes in this domain a *new theory* that may now agree with the *Recent data*.

If however there is still conflict, the above cycle or part of it is repeated. New experiments and new theories can be needed. The development of physical theories may be considered to consist of the chain D-P, L-P, L-P, D-P, D-L-P, and so on, where D-L-P stands for "activities in domain Data followed by activities in domain Logic followed by activities in domain Physics."

The leap made in Stage III takes place in domain Logic and has no physical meaning. It is therefore completely arbitray, as long as logic is maintained, and can be done in an infinite number of ways. Such a leap or a guess cannot be derived in any way. The choice of the leap obviouly takes into account the *Recent data* and is such that the new theory will hopefully remove the *Conflict* in Stage II or agree with new data. If there is no data that can guide the choice, the simplest form of the new mathematical structure may be chosen, as is indicated in Ed ff of Section A3 below.

The choice of new experiments is also in principle arbitrary but is largely aimed at testing the new theories. New technologies can also lead to new or more accurate experiments and thereby produce new or more accurate data. After these experiments, the content on level Data0 will be new *Recent data* which, upon crossing the boundary Data-Physics, tests the theory again.

3. HISTORICAL SURVEY OF PHYSICAL THEORIES

3.1. Criteria in the Formation of New Physical Theories

The steps in Section 2.4 are now applied to the creation processes of established physical theories in Section 3.2 below. The result of this application shows that in the creation processes the following criteria CR1 and CR2 are satisfied.

CR1: Between Stages II and III,
- (a) the only new quantities crossing the boundary Logic-Physics into domain Logic are the *Recent data*, which become recent mathematical requirements to be satisfied by performing suitable leaps in the existing mathematical structure. In particular,
- (b) no physical quantities or concepts foreign to the existing theory in form of any physical hypothesis made in domain Physics make this crossing to become foreign mathematical symbols, relations and requirements that need be compatible with the existing mathematical structure in domain Logic.

CR2: The new theory satisfy the requirements of
- (a) pragmatsim in Section A1,
- (b) the original verifiability principle of logical postivism LPa and LPb in Section A2 and
- (c) Einstein's criteria Ec and Ed in Section A3.

3.2. Historical Cases

In this subsection, the creation processes of the physical theories below are sketched in terms of the stages in Section 2.4. The criterion CR2 is considered to be satisfied in each of the following well-established cases. The criterion CR1 and the levels in domain Logic will be considered separately below.

3.2.1. Copernican Universe ∼1543

Recent data: Astronomical data were acquired for astrological purposes.

Conflict: Increasing number of geocentric models conflicted with each other and disagreed with data. Astronomers disagreed as to whether Venus and Mecury were inside or outside the orbit of the sun. The civil calendar had fallen seriously out of alignment with the sun's positions.

Leap-Hypothesis: The existing mathematical or logical structures are those pertaining to the various geocentrical models. The recent mathematical or logical requirements originate in *Recent data*; CR1 is satisfied. The leap-hypothesis consists of new assignments of the roles of the heavenly bodies and the replacement of geocentrical models by the heliocentric model so that the inconsistencies corresponding to the *Conflict* are removed. The new logical structure remains on level Logic0 because the quantities involved all have their counterparts on level Data0.

3.2.2. Newtonian Mechanics ~1687

Recent data: They were observations by Kepler and others.

Conflict: There was no existing theory in form of differential equations; hence there was no conflict.

Leap-Hypothesis: The definitions and assumptions, to which the mathematical structure of Newton's equations together with the inverse square law of gravity can be reduced to, are taken as the leaps. The new mathematical structures are differential equations and are on level Logic0 because the quantities involved therein, when moved across the boundary Logic-Physics into domain Physics, have all counterparts on level Data0. Since there was no conflict, CR1 does not apply.

3.2.3. Thermodynamics and Statistical Mechanics 1700's and Late 1800's

Recent data: They were work on heat engines for the first topic. For the last topic, chemical and mechanical experiments brought down the caloric theory of heat so that the atomistic view of matter could regain ground.

Conflict: There were no viable existing theories in form of differential equations in these areas; hence there was no conflict.

Leap-Hypothesis: In thermodynamics, it is the impossibility to create perpetuum mobile. Although the concept of caloric was used, it did not cross the boundary Logic-Physics into domain Logic to become a recent mathmatical requirement; CR1 is not violated in practice. The quantities in the equations of thermodynamics are obviously on level Logic0. For statistical mechanics, it is the atomic hypothesis and mechanical nature of heat. The quantities in the associated differential expressions can all be measured and are hence on level Logic0. Since there was no conflict, CR1 does not apply.

3.2.4. Electromagnetism ~1873

Recent data: They were data summarized by the laws of Coulomb, Ampère and Faraday.

Conflict: Ampère's law disagreed with conservation of charge.

Leap-Hypothesis: The existing mathematical strutcures in domain Logic are the above three laws in form of differential equations (with prime $'$ attached to the symbols), which may be considered to have been moved from domain Data via domain Physics into domain Logic. CR1 is therefore satisfied. Among these existing mathematical strutcures, Maxwell discovered an inconsistency corresponding to the

Conflict. The hypothesis corresponding to the leap consists of adding a displacement current(derivative of the electric field with respect to time) to the Ampère law (1), whereby the inconsistency is removed. The quantitites in Maxwell's equations are all measurable and the new mathematical structure is therefore on level Logic0.

Later developments showed that the electric and magnetic fields can be written as derivatives of a vector potential A_μ which in domain Logic satisfies

$$\left(\nabla'^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t'^2}\right) A'_\mu(\underline{x}', t') = j'_\mu(\underline{x}', t') \tag{2}$$

where j_μ denotes the electric current density and c the speed of light. These equations are simpler but are of second order while the Maxwell equations are of first order. A_μ can however not be observed directly and hence do not have any counterpart on level Data0 and (2) is therefore assigned to level Logic1. The mathematical manipulation that converts A'_μ to the fields on level Logic0 is derivation.

3.2.5. Quanta 1900, 1905

Recent data: The black body radiation spectrum was accurately measured and fitted empirically to a formula, the Planck law.

Conflict: This spectrum could not be calculated from clasical physics at that time, which could also not be modified to obtain this law.

Leap-Hypothesis: The established thermodynamics and Boltzmann's statistical mechanics can be brought across the boundary Logic-Physics to become the existing mathematical structures in domain Logic. Apart from that, only the Planck law is brought across the same boundary to become the recent mathematical requirement; CR1 is satisfied. The inconsistency between them corresponding to the *Conflict* is eliminated by introducing the leap $E' = h\nu'$ into the existing mathematical structures. The variables in Planck's law are all measurables and the new mathematical structures are therefore on level Logic0.

The physical meaning of $E = h\nu$ came in 1905, when Einstein noticed that the entropies of low intersity monochromatic radiation and of an ideal gas varried in the same way with the volume and inferred that light behaves also like material particle.

3.2.6. Special Relativity 1905

Recent data: Accurate measurements of the velocity of light c showed that it was the same in different inertial systems.

Conflict: c = constant was inconsistent with absolute time in Newtonian mechanics.

Leap-Hypothesis: The existing mathematical structure is that pertaining to Newtonian mechanics and Galileo transformations. Only c = constant is taken across the boundary Logic-Physics to become the recent mathematical requirement; CR1 is satisfied. The hypothesis corresponding to the leap consists of removal of the above absolute time concept and allow time to be different in different inertial systems. The inconsistency associated with the *Conflict* is now removed in the new mathematical structure pertaining to Lorentz transformations. This structure remains on level Logic0.

3.2.7. General Relativity 1915

Recent data: They were accurate measurements showing that inertial and gravitational masses were equivalent.

Conflict: Lorentz transformations could not accomodate this equivalence.

Leap-Hypothesis: The existing mathematical structure is that pertaining to special relativity. The recent mathematical requirement originates in the equivalence of inertial and gravitational masses; CR1 is satisfied. The first leap consists of replacing Lorentz transformations, in which $g_{\mu\nu}$ are constants, by general nonlinear transformations $g_{\mu\nu}(x_\sigma)$ and thereby the inconsistency due to the *Conflict* is eliminatd. This is followed by the leap in setting the Ricci tensor $R_{\lambda\nu}(g_{\mu\nu}(x_\sigma)$ and its derivatives up to second order$) = 0$, which is the simplest possible choice, in accordance with CR2c Ed ff in Section A3, because there was no guidance from data. $g_{00} - 1$ is identified as the Newtonian gravitational potential, when it is weak, and hence does not have counterpart on level Data0; only the derivative of the gravitational potential is measurable and can appear on level Data0. The other components in $g_{\mu\nu}(x_\sigma)$, identified as the generalized gravitational potentials can analogously not be observed directly. The new mathematical structure and the leap are therefore on level Logic1. The mathematical manipulation that converts $g'_{\mu\nu}(x'_\sigma)$ to fields on level Logic0 is derivation, analogous to the conversion of A'_μ to electric and magnetic fields.

3.2.8. Quantum Mechanics 1923–1926

Recent data: Compton (1923) confirmed that light wave behaves also like material particle.

Conflict: de Broglie (1924) pointed out that this would be inconsistent with that material particle were not considered as wave.

Leap-Hypothesis: Debye said that a wave equation is needed. Schrödinger followed this up and considered the table below, which refers to domain Physics (Goldstein, 1950). Boxes 2 and 3 can be taken across the boundary Logic-Physics into domain Logic to beome the existing mathematical structures. The content of *Recent data* is similarly brought across the same boundary to become the recent logical requirement; CR1 is obeyed. This requirement is fulfilled by the leap that creates the logical counterpart of box 1, which can be derived from box 2. Now an inconsistency corresponding to the *Conflict* arises and is removed by the leap creating box 4. Because the contents of box 1 and box 3 have the same form Hamilton (1834), the form of box 4 is therefore the same as that of box 2. Since the material particle in classical mechanics is a scalar, let its wave function be a scalar function ψ. Replacing A_μ in box 2 by ψ and make use of p in box 3, the Schrödinger equation is obtained in box 4. These last steps take place in domain Physics but can also be considered to have taken place in domain Logic, analogous to the both alternatives mentioned at the end of Section 2.3. The Schrödinger equation is on level Logic1 because ψ' replaces A'_μ in (2).

	Particle description	Wave description
Light	*Box 1*: Eikonal equation of geo-metrical optics in a medium with refractive index n	*Box 2*: Wave Equation (2) with no prime, $j_\mu = 0$, light speed c replaced by $u = c/n$, and frequency ν
Material particle	*Box 3*: Hamilton Jacobian equation with energy E, potential V, mass m, mementum $p = (2m(E - V))^{1/2}$ and	*Box 4*: An analogous wave equation with wave length $\lambda = u/\nu = h/p$; the Schrödinger equation

The manipulation that converts ψ' to quantities on level Logic0 is the formation of expectation values.

3.2.9. Relativistic Quantum Mechanics 1928

Recent data: These were summarized by Schrödinger's equation and special relativity.

Conflict: Schrödinger's equation was inconsistent with special relativity.

Leap-Hypothesis: The Schrödinger equation is taken across the boundary Logic-Physics to become the existing mathematical structure. The same is done to Lorentz transformations which become the recent mathematical requirement; CR1 is satisfied. The inconsistency derived from the *Conflict* is eliminated by the leap that requires that the Schrödinger equation be modified to a new mathematical structure linear in momenta in order to conform to special relativity. The new mathematical structure is that pertaining to Dirac's Equation (C2) and is similarly on level Logic1. The extra ψ' components are on the same level as ψ' in the previous case. The manipulation that converts ψ' to quantities on level Logic0 is the same as that in case *3.2.8*.

3.2.10. Parity Nonconservation 1956

Recent data: The $\tau(K_L)$ and $\vartheta(K_S)$ mesons were found to be the same meson but their decay products had different parities.

Conflict: These results were inconsistent with the view at that time that parity was always conserved.

Leap-Hypothesis: The existing mathematical structure is that pertaining to Dirac's equation or more generally quantum electrodynamics (QED) which conserves parity. The recent mathematical requirement is derived from *Recent data* so that CR1 is satisfied. It corresponds to nonconservation of parity. This inconsistency corresponding to *Conflict* is eliminated by the leap that removes the requirement of parity conservation in the existing mathematical structure when applied to weak interactions. The new mathematical structure later evolved into the Glashow-Salam-Weinberg (GSW) (Glashow, 1961; Salam, 1968; Weinberg, 1967) model for electro-weak interactions. It is on level Logic1, similar to the previous case.

In summary, the criterion CR1, where applicable, is satisfied by all the above classical cases. The mathematical structures for classical physics in cases *3.2.1–6* are om level Logic0. Those for general relativity and quantum physics in cases *3.2.7–10* are on level Logic1.

4. EWM, QCD AND SSI

The steps applied to the above ten cases are now also applied to the current main stream particle theories EWM and QCD and also to SSI.

4.1. EWM 1960's

Recent Data: They were experimental results that follow Section *3.2.10* and the experimental verification of the $W^{\pm}$ and Z gauge bosons.

Conflict: The then existing GSW model did not allow finite masses of these gauge bosons.

Leap-Hypothesis: The existing mathematical structure is that pertaining to the GSW model. The recent mathematical requirement is derived from *Recent data* and CR1 is satisfied in this respect. According to the *Conflict*, it is inconsistent with the existing mathematical structure due to the finite masses of the gauge bosons. In Section 3.2, such inconsistencies have been overcome by leaps performed in the existing mathematical structure in domain Logic. In EWM, however, the hypotheses that the symmetry of vacuum is spontaneusly broken and vacuum consists of Higgs condensate are made in domain Physics. These are then brought across the boundary Logic-Physics to become additional recent mathematical requirements. Because these hypotheses contain concepts absent in the existing GSW structure and in *Recent data*, CR1b is *violated*. Moreover, Higgs boson is not present on level Data0 because it has not been seen. Consequently, it also violates CR2b LPb and CR2c Ec. Further, quark wave functions are put on par with lepton wave functions in the GSM model, contrary to the observation that "no free quark exists" in Section 4.3 below. Thus, it can be shown that the creation of the GSM model itself violates CR1. The new mathematical structure involved is on level Logic1, just like that for the case Section *3.2.10*.

4.2. QCD Early 1970's

Recent data: Experiments on hadrons in the 1950's and 1960's led to the quark (fractionally charged spin 1/2 point particle) hypothesis. Nucleons were found to contain point-like objects, called partons, which could not be shown to be quarks. Although no free quark had been seen, its absence was not fully established experimentally at that time. Therefore, the interpretation was that "quarks are confined" which implied that quarks existed but were somehow confined (see Section B3 below). It differs from that "no free quark exists" in Section 4.3 below. There were also a large amount of data on hadrons.

Conflict: The then existing QED could not account for quark confinement and other hadronic data.

Leap-Hypothesis: The existing mathematical structure is that pertaining to QED. However, the content of *Recent data* about quarks is not taken directly across the boundary Logic-Physics into domain Logic to become recent mathematical requirements, as in the cases of Section 3.2. Instead, this content is modified into the hypotheses that quarks come in 3 colors and interact with each other via gauge fields having 8 colors in domain Physics. These are then brought across the boundary Logic-Physics to become recent mathematical requirements and relations as are seen in (B.1) below. Because these physical quantities and concepts are absent in the existing QED structure and in *Recent data*, CR1b is *violated*. Further, these colored objects are not present on level Data0 because they cannot be observed. Therefore, they also violate CR2b LPb and CR2c Ec. QCD also violates CR2a, CR2b LPb and CR2c Ec because QCD cannot account for low energy hadronic data in PDG (2004). The new mathematical structure involved is formally on level Logic1 but there are no straightforward mathematical manipulations that can convert this structure to level Logic0.

Additional difficuties of QCD are given in Appendix B.

4.3. SSI 1990's

Recent data: Data showed convincingly that "no free quark and no free diquark exist." This differed from the interpretation that "quarks are confined" in Section 4.2 above. There were also a huge amount of data on hadrons.

Conflict: The existing QED, in form of Bethe-Salpeter (BS) equation, could not account for confinement and other hadronic data.

Leap-Hypothesis: The existing mathematical structure is that pertaining to the BS equation The content of *Recent data* regarding quark and diquark, when taken across the boundary Logic-Physics into domain Logic, becomes the recent mathematical requirement that wave functions to be associated with quarks and diquarks cannot be present in the new mathematical structure. The construction of SSI is given in Appendix C and Section C5 shows that CR1 is satisfied. The inconsistency related to confinement in *Conflict* is removed in Hoh (1993, 1994). The new mathematical structure involved is on level Logic2.

Summarizingly, the criteria CR1 are CR2 are satisfied by SSI but not by EWM and QCD. The mathematical structures of EWM and QCD are fomally on level Logic1. For SSI, it is on level Logic2.

5. INTERACTION OF PARTICLE THEORIES WITH EPISTEMOLOGY

5.1. Hypotheses on Vacuum

Vaccum can carry gravitational and electromagnetic energies and waves and can yield particle-antiparticle pairs. In the late 1940's, vacuum was found to be slightly polarizable by electromagnetic fields and such effects are exactly calculated in QED. The virtual particles in QED are however *not new*, but have observable counterparts.

Comtemporary hadron physicists believe that vaccum can also carry other types of *new, not observed* media. In EWM, vacuum is assumed to be a Higgs condensate. For color confinement in QCD, vacuum is assumed to be a perfect color dia-electric. These virtual media have however no observable counterparts and these two vacua hence differ from the QED vacuum in this respect.

Attempts to resort to vacuum as a means to explain physical phenomena are not new. Over a century ago, the "vacuum" at that time was thought to be filled by a universal ether in which light propagates and this view was widely accepted by physicists. It persisted in spite of the fact that Maxwell's theory of light does not require any ether but was finally brought down by special relativity.

Over two centuries ago, the then "vacuum" was analogously thought to contain a hypothetical weightless fluid known as caloric representing heat. This caloric hypothesis helped Carnot to arrive at his discoveries in thermodynamics and was widely accepted in the 1700's. But by the mid-1800's, many kinds of experiments showed that heat is a form of mechanical energy and the caloric concept had to be abandoned.

These earlier "vacua" however did not interfere with the mathematical formalisms of Huygens and Carnot. The difficulties were comceptual. The "vacua" in EWM and QCD also differ from these earlier ones in that they are specific and characterize the mathematical formalisms.

Nevertheless, this is some resemblance between these two "vacua" and the two earlier ones. The caloric concept held for more than a century. The history of ether was even longer. Judging from these time scales, the concepts of vacuum as Higgs condensate and color dia-electric may continue to prevail for some time to come. However in a few years, when the Large Hadron Collider will deliver data, the existence of Higgs boson will face a decisive test.

5.2. Level Logic0

As was mentioned at the end of Section 3, the mathematical structures (differential equations) for physical theories up to about 1910 are on level Logic0. As was defined in Section 2.2, level Logic0 can be "seen" form level Data0 via domain Physics. The left part of Fig. 1 concerns these levels. The concepts are therefore all familiar and "Gedanken" or thought experiments, so forcefully employed by Einstein and Bohr, could be performed. The results of algebraical manipulations on this level can likewise be "understood" in terms of known concepts.

5.3. Level Logic1 and Its Implications

The mathematical structures for general relativity and quantum physics are on level Logic1. Because level Logic1 is "hidden" from direct view from level Data0 across domain Physics, new degrees of freedom become possible. In quantum mechanics, such a freedom is expressed in form of the existence of an arbitrary local phase associated with a wave function which is a hidden dependent variable. This arbitrary phase in its turn necessitates a U(1) gauge field, identified as the electromagnetic field.

In addition, purely quantum mechanical effects having no counterparts on level Data0 before quantum mechanics, such as exchange effects, tunnelling, Bose-Einstein condensation, etc, emerge. These new physics comes from mathematical operations on level Logic1 and cannot be "understood," like we "understand" Newtonian mechanics, because the associated concepts are unrelated to the then known concepts on level Data0 (see Section 5.5 below). Words like "tunneling" (osmosis or infiltration could as well be used instead) are names assigned to certain mathematical results, confirmed by data, so as to give us some feeling what they are like in terms of familiar concepts.

Einstein's standpoint, that quantum mechanics offers no useful point of departure for future development, was based upon the hypothesis of "spatial separability," a result of "Gedanken" experiment, applied to Schrödinger's ψ (Einstein's autobiography, 1949). This viewpoint is untenable here; "Gedanken" experiments make use of familiar concepts on level Logic0 and cannot be reliably initiated from level Logic1. This hypothesis was introduced in domain Physics and hence violates CR1b.

The purely quantum mechanical results can only be accepted as new concepts that one "gets used to" them after some time.

5.4. Level Logic2 and Its Implications

This section concerns the right part of Fig. 1 which commences in the 1990's. Level Logic2 is still farther away and more "hidden" from direct view from level Data0, as was predicted in Ed ff of Section A3. Therefore, still more freedoms are allowed on this level, as is evidenced by choices of the forms of quark-antiquark interaction, the mass operators and the meson internal or flavor functions in Appendix C. Here, the example set in Section *3.2.7* and the "inner perfection" criterion Ed of Section A3 come to aid.

The hidden independent variables on this level allow for new physics not obtainable on level Logic1. These include the relative space $\underline{x}$ and relative time x^0 between quarks (see (C.22) below) which give rise to confinement and finite $W^{\pm}$ and Z boson masses(without Higgs boson), respectively, in SSI considered in Appendix C.

The internal or flavor coordinates z_I, z_{II} in (C.23–C.24) below can be considered to be on par with the "hidden" relative space coordinate x mentioned above. Thus, the mass operator $m_{2op}(z_I, z_{II})$ in (C.24) may for instance be generalized to $m_{2op}(z_I, z_{II}, x)$ such that Lorentz invariance is preserved. The internal or flavor space $z_I z_{II}^*$, when real, and the relative space $\underline{x}$ between quarks are now coupled and this may lead to additional new physics. This may be related to that the masses of mesons with closed flavors($z_I z_{II}^*$ real) differ somewhat from the predictions in Table 5.5 of Hoh (2005).

5.5. Physics Comes Out of Mathematics

The results obtained from levels Logic1 and Logic2 cannot be "understood" at first. This is due to that we can only "understand" by referring back to familiar concepts. However, the physics that arises from mathematics on these two levels are associated with new, unknown concepts which can therefore not be "understood." A theorist's task is to provide a concise "account," not "explanation," of data, here using partial differential equations and their solutions. Whether the new concepts in the account can be "explained" or "understood" or not is of no concern in the beginning. Eventual "understanding" may come later when people get used to such new concepts because they work.

CR1 of Section 3.1 does not allow physical quantities or concepts outside the existing theory and *Recent data* in domain Physics to be "put into" domain Logic. From the new mathematical structure obtained in domain Logic, however, comes new physical concepts when this structure is brought into domain Physics to become a new theory. As Weisskopf has pointed out: physics comes out of mathematics.

Examples are time dilatation and Lorentz contraction on level Logic0, red shift, curved space time, quantum mechanical exchange effects and tunneling, and Bose-Einstein condensation on level Logic1, and confinement and mass generation for the $W^{\pm}$ and Z gauge bosns (without Higgs boson) in SSI on level Logic2. Apart from those on level Logic0, these new concepts cannot be obtained by manipulations of the old concepts, such as "Gedanken" experiments or constructions of phenomenological models because these can only contain known, hence not new, concepts. The Bohr-Sommerfeld models and potential models for hadron spectra are examples.

The *Conflict* in Stage II of Section 2.4 is not resolved in that stage in domain Physics. It is resolved in Stage III, in which the *Conflict* turns into an *Incocsistency* that is eliminated by the *Leap*. This leap is the *turning point* in the stages of development in Section 2.4 and is of purely logical nature or some general principle because Stage III takes place in domain Logic.

In the cases of Sections 4.1–4.2, however, physical quantities and concepts (Higgs bosons, colored objects) foreign to the existing theories are created in Stage II in domain Physics in form of hypotheses which are then "forced" into domain Logic in Stage III. This violates of CR1 of Section 3.1. These concepts have their origins in analogies with existing physical concepts in solid state physics and are basically old. In fact, any physical hypothesis created in this stage can invariably only contain known, hence old, physical concepts because these are the only ones we have at our disposal.

These specific, second guesses of nature fix beforehand the directions of subsequent developments in domain Logic in Stage III and thereby deprive nature of the possibility to take its own course through mathematical developments from a more "loose" and general new mathematical structure, observing CR1, as in the cases of Section 3.2. CR1 means that physical hypotheses cannot "move" in the direction from domain Physics in Stage II into domain Logic in Stage III to become leaps or additional recent mathematical requirements. If it is not heeded, the new mathematical structure will be forced to live with forms of old concepts that may thwart the emergence of genuinely new physics. This is also the case for phenomenological models which are therefore stop-gap theories having narrow, specific application angles.

The direction of "motion" is the opposite. It is the *Leap,* which is logical and not physical, made in Stage III in domain Logic that "moves" into domain Physics in Stage IV to be suitably interpreted as a physical *Hypothesis.*

5.6. Impact of Quark Physics on Our Conception of the Universe

Up to a century ago, people's daily experiences and concepts formed from them originated in the Newtonian world. Time was absolute, space Euclidean and physics continuous and deterministic. The parameter region in which this Newtonian conception of the universe holds were subsequently expanded by new experiments and this conception had to be modified in the new parameter regions.

Thus, at high speeds, the above space and time become relative and interconnected to become space-time according to special relativity. Considering the large masses of the heavenly bodies, the above space-time become connected to mass to become space-time-mass or "curved space-time" in accordance to general relativity. In the atomic region, the continuous and deterministic conceptions of the universe become discrete and statistical described by quantum mechanics.

The emergence of quarks and the theories to account for them again introduce new conceptions in the subnuclear region of parameters. The new feature is the "hidden relative space-time x" and "hidden complex flavor space z" (see Section C5 and Section C1 below) or shortly "hidden space" necessitated by that quarks are not observable individually. Such "hidden spaces," or synonymously "hyperspace", are not limited to SSI here but have to be present in any realistic hadron theory containing quarks at different space-times so that the first line of (C.22) below holds. There is at least one "hidden spaces" or "hyperspaces" associated with each hadron. Thus, *our conception of the universe now includes infinitely many such "hidden spaces," in which essential physics takes place.*

Conventionally, hadrons are conceived to have finite sizes in laboratory space. However, such sizes are inferred from experiments involving collisions and do not necessarily apply to a hadron not under interaction. Such a hadron is described by the wave equations (C.23) or (C.25) and (C.22) applies. After having solved these equations and integrated ove the "hyperspaces," the wave functions reduced to the exponential form in (C.22) which describes a free point particle in laboratory space X^μ. This puts the hadron on equal footing with the lepton; the difference is that the hadron, but not the lepton, is accompanied by "hidden relative spaces."

Thus, *the four dimensional space time X^μ we live in contains only vacuum and point particles and is entirely "empty."* This conception is not new but has for instance been arrived at long ago by buddists in akin form.

Classical physical theories were largely constructed from observed data. Thus, Maxwell set out to put Faraday's experimental results in mathematical form which became part of his theory and Kepler's data played role in the formation of Newton's theory. The newer ones, such as those mentioned in Sections *3.2.7–8* were no longer constructed in that way but were "guessed mathematically," based upon earlier mathematical forms, hints from data, intuition, and the criteria of Section A3 Ec–Ed below.

The basic language of nature may be considered to be solutions to partial differential equations. New concepts derived from these equations represent the basic features of that part of nature pertaining to these equations and have no counterparts in the Newtonian world. This is why ordinary people, including some philosophers not familiar with the creation process of newer physical theories, find the new physics difficult to "understand."

6. CONCLUSIONS

Past experiences show that in the creation of a new physical theory, one does not put in physics, which invariably refer to known concepts, into new theories but relies on logic or some basic principles in the creation of the new mathematical structure. New physics and concepts then comes out of mathematics development from this structure.

These experiences in form of CR1 were not heeded in the creation processes leading to EWM and QCD, as was mentioned in Section 5.5. CR2 is also not fulfilled. Appendix B indicates further that difficulties of QCD are too fundamental to be overcome by modifications. From epistemological as well as historical viewpoints, the Higgs related part of EWM and low energy QCD therefore appear to be stop-gap theories to be replaced by a more correct theory, for which SSI may be a candidate.

APPENDIX A: RELEVANT EPISTEMOLOGIES

Ever since renaissance, scientists and philosophers have influenced each other. Copernicus and Galilei influenced Descartes, who in his turn influenced Newton who influenced Kant. Hume and Mach influenced Einstein who influenced the Vienna Circle. Many of the philosophers had scientific background or started off as scientists. On the whole, science had more impact upon epistemology than vice versa.

Four epistesmologies of interest to the present investigations are sketched below for reference.

A1. Pragmatism (Encyclopedia Britannica)

"Pragmatism is a school of philosophy founded by Peirce (1877) . . . It is based on the principle that the usefulness, workability, and practicality of ideas and proposals are the criteria of their merit. Ideas borrow their meanings from their consequences and their truths from their verification.

Peirce's pragmatism is primarily a theory of meaning that emerged from his first-hand reflections on his own scientific work, in which the experimentalist understands a proposition as meaning that, if a prescribed experiment is performed, a stated experience will result. The method has two different uses: (1) It is a way of showing that when disputes permit no resolution, the difficulties are due to misuses of language, to subtle conceptual confusions. (2) The method may be employed for clarification. Consider what effects, that might conceiveably have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object."

Peirce' also introduced the term *retroduction*, which means the forming and accepting on probation of a hypothesis to explain surprising facts. This was once his main theme of pragmatism.

A2. Logical Positivism (Encyclopedia Britannica)

Logical Positivism comes out of the Vienna Circle (1923–1938) founded by Schlick. Einstein (special relativity) had significant impact on it. Its members paid much attention, firstly, to the form of scientific theories, in the belief that the logical structure of any particular scientific theory could be specified quite apart from its content. Second, they formulated a "verifiability principle" or criterion of meaning, a claim that the meaningfulness of a proposition is grounded in experience and observation. In its negative form, the principle said that no statement could both be a statement about the world and have no method of verification attached to it. In other words, all *meaningful* discourse consists either of

LPa: the formal sentences of logic and mathematics, or
LPb: the factual propositions of the special sciences. Any assertion that claims to be factual has meaning only if it is possible to say how it might be verified. Metaphysical assertions, coming under neither of the two classes, are meaningless.

Because this principle is by itself not verifiable, they could only recommmend its use. During 1930–1960, verifiability was replaced by a more tolerant version expressed in terms of testability or confirmability. The logical positivists continued to reformulate their criteria of factual meaningfulness. There are different versions; all of them are more lenient then the stringent original formulation.

A3. Einstein's Epistemological Credo (Einstein's Autobiography, 1949)

Einstein saw on the one side

Ea: the toality of sense-experiences, and
Eb: the totality of concepts and propositions on the other. The relations between the concepts and propositions among themselves and each other are of a logical nature and follow firmly laid down rules.

He wrote further: "The concepts and propositions get "meaning," viz., "content," only through their *connection* with sense-experiences. The connection of the latter with the former is purely intuitive, not itself of a logical nature. The degree of certainty with which this connection, viz., intuitive combination, can be undertaken, and nothing else, differentiates empty phantasy from scientific "truth." The system of concepts is a creation of man together with the rules of syntax, which constitute the structure of the conceptual systems. Although the conceptual systems are logically entirely arbitrary, they are bound by the aim to permit the most nearly possible certain (intuitive) and complete coordination with the totality of sense-experiences; secondly they aim at greatest possible sparsity of their logically independent elements (basic concepts and axioms), i.e., undefined concepts and underived (postulated) propositions .... A proposition is correct if, within a logical system, it is deduced according to the accepted logical rules. A system has truth-content according to the certainty and completeness of its coordination-possibility to the totality of experience. A correct proposition borrows its "truth" from the truth-content of the system to which it belongs. Judgement of the theory is based upon the both conventions:

Ec: "external confirmation." The theory must not contradict empirical facts evenif its application can be quite delicate. For it is often, perhaps even always, possible to adhere to a general theoretical foundation by securing the adaptation of the theory to the facts by means of artificial additional assumptions ...
Ed: "inner perfection." This is characterized by the "naturalness" or "logical simplicity" of the premises of the basic concepts and of the relations between these which are taken as a basis.

Among theories of equally "simple" foundation that one is to be taken as superior which most sharply delimits the qualities of systems in the abstract i.e., contains the most definite claims .... We prize a theory more highly if, from the logical standpoint, it is not the result of an arbitrary choice among theories which, among themselves, are of equal value and analogously constructed ... *in the choice of theories in the future will have to play an all the greater role the more the basic concepts and axioms distance themselves from what is directly observable, so that the confrontation of the implications of theory by the facts becomes constantly more difficult and more drawn out* ... A theory is the more impressive in the greater the simplicity of its premises is, the more different to kinds of things it relates, and the more extended is its area of applicability."

A4. Feyman's Summary

Today's physicists follow the above epistemologies to varying degrees without thinking about them. These teachings have been summarized, among others, in Feynman's lectures:

> One guesses a theory and computes its consequences. If the results disagree with experiment, this theory is wrong. If the results agree with experiment, it does not mean that this theory is right.

APPENDIX B: ON THE FOUNDATION OF QCD

Apart from the remarks in Section 4.2 that the creation of QCD does not satisfy CR1 and at least part of CR2, the following points show that the foundation of QCD is far from being firm.

B1. QCD at High Energies

That QCD is allegedly successful at high energies does not mean that it is right (Section A4). Further, this allegation is not stringent. An often cited agreement with data comes from deep inelastic scattering experiments but the test is on the level of structure function, which contains assumptions so that the derived results are no longer firmly anchored in first principles.

The circumstance may be compared to that classial mechanics agrees with data at high angular momenta but breaks down at small angular momenta and has to be replaced by quantum mechanics. Somewhat similarly, QCD holds perturbatively at high energies but becomes nonperturbative around 1 Gev and cannot produce predictions without resorting to assumptions or phenomenological models. In the low energy region, QCD analogously needs be replaced by another theory; SSI may be a candidate. Such a theory, at higher energies, has to go over to a form that will yield results compatible to those of perturbative QCD; there may be an equivalent "correspondence principle" analogous to that taking quantum mechanics to classical mechanics.

B2. Experimental Evidences

An important underpinning of QCD is provided by the three jet data from the JADE experiments in 1979. One of the jets differed from the other two, could be associated with a spin one structure and was assigned to a jet spear-headed by a gluon. However, this underspinning is removed if the gluon is replaced by a diquark, which has a spin one and is also not observable. The diquark interpretation is consistent with the successful quark-diquark claasification of baryon spectra.

Further, the predicted glueball has not been observed.

The so-called quark-gluon plasma experiments start with nucleons whose mutual interaction is scalar. In the plasma state, however, the interaction among quarks takes place via colored vector gauge fields. It is not clear how these two widely different types of interactions can "convert" into each other.

B3. QCD Action

In the notation of PDG (2004), the QCD Lagrangian reads

$$L_{\text{QCD}} = -\frac{1}{4} F_{\mu\nu}^{(a)} F^{\mu\nu(a)} + i \sum_q \bar{\psi}_q^i \gamma^\mu (D_\mu)_{ij} \psi_q^j - \sum_q m_q \bar{\psi}_q^i \psi_{qi} \quad \text{(B.1)}$$

$$F_{\mu\nu}^{(a)} = \partial_\mu A_\nu^a - \partial_\nu A_\mu^a - g_s f_{abc} A_\mu^b A_\nu^c \quad \text{(B.2)}$$

$$(D_\mu)_{ij} = \delta_{ij} \partial_\mu + i g_s \sum_a \frac{\lambda_{i,j}^a}{2} A_\mu^a \quad \text{(B.3)}$$

where the $\psi_q^i(x)$ are the 4-component Dirac spinors associated with each quark field of (3) color i and flavor q, and $A_\mu^a(x)$ are the (8) Yang-Mills (gluon) fields.

As was mentioned in Section 2.2, the starting points of all established physical disciplines are all differential equations. These can subsequently be converted into action integrals. QCD, however, also breaks this rule in that it starts with an action integral with Lagrangian density (B.1). Equations of motion derived from the QCD action involve quantities on level Logic0 such as colored electric and magnetic fields that have no corresponding quantities on level Data0 and can hence not be measured.

That (B.1) contains quark wave fucntions $\psi_q^i(x)$ reflects the view of *Recent data* in Section 4.2 that quarks exist but are somehow confined. Here, quarks are treated as if they can be observed, contrary to experience, because one can in principle form expectation values, on level Logic0, of dynamic variables using these $\psi_q^i(x)$ on level Logic1. Confinement may be regarded as a "papering over" via the attachment of three colors indices i to each $\psi_q(x)$. This is different from the *Recent data* for SSI in Section 4.3, where the interpretation "no free quark exists" is adopted. This is reflected in that the hadron wave Equations (C.21), (C.23) and (C.25) below contain no quark wave functions.

Practically, there are also no simple ways to obtain hadron wave functions from (B.1–B.3) so that CR2a is not fulfilled.

B4. Applicabiblity of "Asymtotic Freedom" (Gross and Wilczek, 1973; Politzer, 1973)

In QCD, phenomenological confinement is obtained if the vacuum is a perfect color dia-electric. This is allegedly supported by "asymtotic freedom." But this result was derived from an extension of QED(U(1), Abelian), which provides a tiny screening effect, to quarks belonging to an SU(n) multiplet (non-Abelian), which led to anti-screening. Now the charged leptons are directly observable point particles interacting via a U(1) gauge field in QED. The derivation cannot be simply taken over to apply to the not directly observable quarks. From this viewpoint, this "asymtotic freedom" provides no support to confinement.

APPENDIX C: SSI (SCALAR STRONG INTERACTION HADRON THEORY)

The background leading to SSI (Hoh, 1993, 1994, 1996, 1999) has been given in Hoh (2005). Here, it is summarized taking Section 2 and Section 3.1 into consideration. Unless specified to be otherwise, the symbols and formulae below are taken to refer to hypothetical cases and are within domain Logic but with the primes $'$ dropped for simplicity.

The physics mentioned below serve to aid in the choices of leaps which are in principle arbitray and hence infinte in number on level Logic2, so that when the completed new mathmatical structure is taken across the boundary Logic-Physics into domain Physics in Fig. 1, it becomes a new theory that can be tested favorably against data from level Data0.

C1. Internal or Flavor Space

The Dirac equation in classical form reads

$$\gamma^{\mu} p_{\mu} + m = 0 \tag{C.1}$$

where p_{μ} is the 4-momentum and m the mass of a particle. When going over to quantum mechanics, the momenta p_{μ} become operators operating on a wave function so that (C.1) becomes the Dirac equation

$$(-i\gamma^{\mu}\partial_{X\mu} + m)\psi(X) = 0 \tag{C.2}$$

Now, both p_μ and m are measurable quantities and should be treated on equal footing. Therefore, m should also be generalized into an operator m_{op} operating on some function ξ. This conception originated in the early 1960's and hadron masses were regarded as expectation values of mass operators. This led to the successful classification of hadron masses by the Gell-Mann-Okubo formula (Okubo, 1962). Referring to quarks, (C.2) is thus generalized to

$$(-i\gamma^\mu \partial_{X\mu} + m_{op})\psi(X)\xi^p(z^q) = 0 \tag{C.3}$$

where the superscripts p and q designates quark flavor and z^q represents a complex internal or flavor space of dimension equal to the number of quark flavors under consideration. To begin with, let $p,\ q = 1,\ 2,\ 3$ which refer to the $u,\ d,$ and s quarks, respectively. These z^q coordinates are not observable and hence are hidden independent variables on level Logic2. They constitute the basis vectors generating the first fundamental representation of the group of global SU(3) transformations. $\xi^p(z)$ transforms as z^p, but its form, as well as that of m_{op}, are arbitrary provided that

$$m_{op}\xi^p(z^q) = m_p\xi^p(z^q) \tag{C.4}$$

where m_p is the mass of the quark with flavor p. Thus, (C.2) can be replaced by (C.3) and (C.4).

Following the thesis of Section A3 Ed, employed in Section *3.2.7*, the simplest forms of the quantities in the eigenvalue Equation (C.4) are

$$\xi^p(z) = z^p, \qquad m_{op} = \sum\nolimits_q m_q \left(z^q \frac{\partial}{\partial z^q} + c.c \right) \tag{C.5}$$

where m_{op} will be called a mass counting operator. These assumptions are analogous to the leap in the general relativity case of Section *3.2.7* and are in accordance with Ed ff in Section A3; the simplest forms are chosen in the absence of physical requirements.

C2. van der Waerden's Equations

Since the advance of special relativity, the basics equations of classical mechanics and electromagnetism have been written in invariant (tensor) forms which garantee their Lorentz invariance. Dirac's equation (C.2) is however not in such a form. This has remedied by van der Waerden (1929) who rewrote this equation in the form

$$\partial_X^{a\dot{b}}\chi_{\dot{b}}(X) = im\psi^a(X), \quad \partial_{X\dot{b}c}\psi^c(X) = im\chi_{\dot{b}}(X) \tag{C.6}$$

where a and b (with a dot above b) are spinor indices running from 1 to 2 and ψ^a and χ_b (with a dot above b) are two-spinors. Equation (C.6) is by its spinor form manifestly invariant under the SL (2,C) group of transformations, which include

Lorentz transformations. The relations between the undotted and dotted spinors and Dirac's wave functions ψ_1, ψ_2, ψ_3, and ψ_4 in (C.2) are

$$\begin{array}{lll} \text{Right handed :} & \chi_{\dot{1}} = \psi_1 + \psi_3, & \chi_{\dot{2}} = \psi_2 + \psi_4 \\ \text{Left handed :} & \psi^1 = \psi_1 - \psi_3, & \psi^2 = \psi_2 - \psi_4, \end{array} \tag{C.7}$$

ψ_3 and ψ_4 are small components which vanish in the relativistic limit and (C.2) is suitable when considering nonrelativistic problems. Quarks are however relativistic and the two-spinor form of the wave functions in (C.7) is more natural.

Taking the complex conjugate of (C.6) yields for the corresponding antiparticle,

$$\partial_X^{b\dot{a}} \chi_b(X) = im\psi^{\dot{a}}(X), \qquad \partial_{X\dot{c}b}\psi^{\dot{c}}(X) = im\chi_b(X) \tag{C.8}$$

Noting (C.4), the equivalent of (C.3) becomes for a hypothetical quark

$$\begin{aligned} \partial_X^{a\dot{b}} \chi_{\dot{b}}(X)\xi^p(z^q) &= im_{op}\psi^a(X)\xi^p(z^q), \\ \partial_{X\dot{b}c}\psi^c(X)\xi^p(z^q) &= im_{op}\chi_{\dot{b}}(X)\xi^p(z^q) \end{aligned} \tag{C.9}$$

$$\begin{aligned} \frac{\partial_X^{a\dot{b}} \chi_{\dot{b}}(X)}{\psi^a(X)} &= i\frac{m_{op}\xi^p(z^q)}{\xi^p(z^q)} = im_p, \\ \frac{\partial_{X\dot{b}c}\psi^c(X)}{\chi_{\dot{b}}(X)} &= i\frac{m_{op}\xi^p(z^q)}{\xi^p(z^q)} = im_p \end{aligned} \tag{C.10}$$

The last line shows that the quark mass m_p is a separation constant between the space time coordinates X and the internal or flavor coordinates z^q.

For the corresponding antiquark, one takes the complex conjugate of (C.9) to obtain

$$\begin{aligned} \partial_X^{b\dot{a}} \chi_b(X)\xi_p(z_q) &= im_{op}\psi^{\dot{a}}(X)\xi_p(z_q), \\ \partial_{X\dot{c}b}\psi^{\dot{c}}(X)\xi_p(z_q) &= im_{op}\chi_b(X)\xi_p(z_q) \end{aligned} \tag{C.11}$$

$$z_q = (z^p)^* = x(z_1, z_2, z_3) \tag{C.12}$$

C3. Starting Equations

Under *Conflict* in Section 4.3, the BS equation was considered as the existing theory. Consider at first the meson case. Let the quark therein be labeled A and be located at x_I and the antiquark therein be labeled B and be located at x_{II}. The BS equation for a system of this type is of the form

$$\begin{aligned} &\left(i\gamma_I^\mu \partial_{I\mu} - m_A\right)\left(i\gamma_{II}^\nu \partial_{II\nu} - m_B\right)\psi_{BS}(x_I, x_{II}) = \text{interation terms}, \\ &\qquad \partial_{I\mu} = \frac{\partial}{\partial x_I^\mu}, \quad \partial_{II\nu} = \frac{\partial}{\partial x_{II}^\nu} \end{aligned} \tag{C.13}$$

The left side is obtained by multiplying the left side of (C.2) applied to quark A by the same applied to antiquark B together with the genealization

$$\psi_A(x_I)\psi_B(x_{II}) \to \psi_{BS}(x_I, x_{II}) \tag{C.14}$$

The BS Equation (C.13) has successfully applied to positronium but obviouly fails for meson in which the quark-antiquark interaction is not electromagnetic. If the electron and positron have large enough energy, they are no longer bound and can hence be free. This is contrary to the meson case in which the quark and antiquark cannot be free. Therefore, the quark-antiquark interaction must be of another kind. Further, the BS amplitude (C.14) has 16 components, far too many for application to mesons. This suggests that the form (C.2) leading to (C.13) does not provide a suitable starting point. As was pointed out below (C.7), the van der Waerden form (C.6) is more suited to represent quarks.

As to the choice of the quark-antiquark interaction, there are in principle infinte many possibilities. In the absence of physical requirements, the simplest form, namely scalar interaction, is chosen. This is entirely analogous to the reasoning underlying (C.5) and the leap in Section *3.2.7* and is in accordance with Ed ff in Section A3. Further, such an interaction is suggested by the known scalar nucleon-nucleon strong interaction.

With these two departures from the BS equation, the present starting points are (C.6) complemented by a scalar inteaction term V and applied to quark A at x_I and (C.8), after raising and lowering indices, analogously complemented and applied to antiquark B at x_{II}. Instead of (C.13), one starts with

$$\partial_I^{a\dot{b}}\chi_{A\dot{b}}(x_I) - iV_B(x_I)\psi_A^a(x_I) = im_A\psi_A^a(x_I) \tag{C.15a}$$

$$\partial_{I\dot{b}c}\psi_A^c(x_I) - iV_B(x_I)\chi_{A\dot{b}}(x_I) = im_A\chi_{A\dot{b}}(x_I) \tag{C.15b}$$

$$\Box_I V_B(x_I) = \tfrac{1}{2}g_s^2\left(\psi_B^b(x_I)\chi_{Bb}(x_I) + \psi_B^{\dot{b}}(x_I)\chi_{B\dot{b}}(x_I)\right) \tag{C.15c}$$

$$\partial_{II\dot{e}f}\chi_B^f(x_{II}) - iV_A(x_{II})\psi_{B\dot{e}}(x_{II}) = im_B\psi_{B\dot{e}}(x_{II}) \tag{C.16a}$$

$$\partial_{II}^{d\dot{e}}\psi_{B\dot{e}}(x_{II}) - iV_A(x_{II})\chi_B^d(x_{II}) = im_B\chi_B^d(x_{II}) \tag{C.16b}$$

$$\Box_{II} V_A(x_{II}) = \tfrac{1}{2}g_s^2\left(\psi_A^b(x_{II})\chi_{Ab}(x_{II}) + \psi_A^{\dot{b}}(x_{II})\chi_{A\dot{b}}(x_{II})\right) \tag{C.16c}$$

Here, g_s^2 is the scalar strong coupling constant for quark-antiquark or quark-quark interaction. The terms in (C.15a, C.15b) and (C.16a, C.16b) are grouped such that the left sides only contain operators in space time and the right sides contain the quark masses which refer to internal space, as is seen in (C.4). Equations (C.15c) and (C.16c) are written such that the potentials are on the left side and wave functions on the right.

C4. Construction of Meson Wave Equations

Analogous to the formal construction of (C.13), the left and right sides of (C.15) are multiplied into the left and right sides, respectively, of (C.16). There are $3 \times 3 = 9$ equations, in which the operators are placed to the left of the wave functions. Similar to (C.14), the separable product wave functions are generalized into two-quark wave functions not separable in x_I and x_{II} according to

$$\chi_{A\dot{b}}(x_I)\chi_B^f(x_{II}) \to \chi_{\dot{b}}^f(x_I, x_{II}),$$
$$\psi_A^c(x_I)\psi_{B\dot{e}}(x_{II}) \to \psi_{\dot{e}}^c(x_I, x_{II}) \tag{C.17a}$$

$$\chi_b^{*\dot{f}}(x_I, x_{II}) = \left(\chi_{\dot{b}}^f(x_I, x_{II})\right)^*, \qquad \chi \to \psi \tag{C.17b}$$

$$\chi_{A\dot{b}}(x_I)\psi_{B\dot{e}}(x_{II}) \to \chi_{\dot{b}\dot{e}}(x_I, x_{II}) \tag{C.18a}$$

$$\psi_A^c(x_I)\chi_B^f(x_{II}) \to \psi^{cf}(x_I, x_{II}) \tag{C.18b}$$

$$V_A(x_{II})V_B(x_I) \to \Phi_m(x_I, x_{II}) \tag{C.19}$$

The mixed spinor χ_b^f (dot over *b*) of (C.17a) has four components, which ccorrespond to those of a conventional 4-vector. It is therefore decomposable into a singlet and a triplet, which can be assigned to the rest frame pseudoscalar and vector meson wave functions, respectively. The same holds for ψ_e^c (dot over *e*). The complex conjugates of the mixed spinors of second rank (C.17b) are still mixed spinors and behave in the same way under SL (2,C) transformations.

χ and ψ on the left of (C.18) can be transposed and this leads to that the right members of (C.18) are symmetric spinors of second rank each having three components only. They can therefore not represent the pseudoscalar meson. In view of the indistinguishability of a quark and an antiquark inside a meson in the context mentioned at the end of Section 2.1 of Chapter 2 in Hoh (2005), ψ^{cf} and χ^{be} (dot over *b*, *e*) of (C.18) are associated with a diquark or an antidiquark from the space time and transformation points of view. ψ^{cf} and χ_{be} (dot over *b*, *e*) are put to zero here in accordance with that "no free diquark exists" under *Recent data* in Section 4.3.

The quark wave functions ψ and χ not paired off according to (C.17) and (C.18) are also put to zero, in accordance with that "no free quark exists" under *Recent data* in Section 4.3. This differs from the interpretation "quarks are confined" in Section 4.2 which led to the presence of quark wave functions in (B.1). Accordingly, the unpaired V_A or V_B also vanishes by virtue of (C.15c) and (C.16c).

Applying (C.17–C.19) to the 9 product equations and noting the above null results, 6 of them drop out. The three surviving equations arise from the products of (C.15a) with (C.16a), (C.15b) with (C.16b) and (C.15c) with (C.16c). The last product necessitates (C.19) because the right side is no longer separable in x_I and x_{II} after application of (C.17–C.18).

The result is the following three coupled meson wave equations,

$$\partial_I^{a\dot{b}}\partial_{II\dot{e}f}\chi_{\dot{b}}^{f}(x_I, x_{II}) + (m_A m_B - \Phi_m(x_I, x_{II}))\psi_{\dot{e}}^{a}(x_I, x_{II}) = 0 \quad \text{(C.20a)}$$

$$\partial_{I\dot{b}c}\partial_{II}^{d\dot{e}}\psi_{\dot{e}}^{c}(x_I, x_{II}) + (m_A m_B - \Phi_m(x_I, x_{II}))\chi_{\dot{b}}^{d}(x_I, x_{II}) = 0 \quad \text{(C.20b)}$$

$$\Box_I\Box_{II}\Phi_m(x_I, x_{II}) = -\frac{g_s^4}{4}(\psi^{b\dot{a}}(x_I, x_{II})\chi_{\dot{a}b}^{*}(x_I, x_{II}) + \psi^{*a\dot{b}} \times (x_I, x_{II})\chi_{\dot{b}a}(x_I, x_{II})) \quad \text{(C.21)}$$

If the quark-antiquark interaction is chosen to be vector (gauge) instead of scalar, similar calculations show that no self-consistent set of meson wave equations like (C.20–C.21) can be formed.

C5. Hidden Independent Variables, Level Logic2 and CR1

The quark and antiquark coordinates x_I and x_{II} are not observables. They are transformed into an observable laboratory coordinate X^μ for the meson and a relative coordinate x^μ according to

$$x^\mu = x_{II}^\mu - x_I^\mu, \quad X^\mu = (1 - a_m)x_I^\mu + a_m x_{II}^\mu,$$
$$\chi_{\dot{b}}^{f}(x_I, x_{II}) = \chi_{\dot{b}}^{f}(X, x) \to \chi_{\dot{b}}^{f}(x)\exp(iK_\mu X^\mu), \qquad \chi \to \psi \quad \text{(C.22)}$$

when a_m is a constant and K_μ the 4-momentum of the meson. The arrow refers to cases separable in X and x. x^μ is also a hidden independent variable and belongs to level Logic2. It cannot be observed so that the requirement that the "no free quark exists" in Section 4.3 is fulfilled. If x^μ were observable, the quark and antiquark coordinates x_I and x_{II} would also be observable according to (C.22), contrary to data.

Analogous to the transition of (C.6) to (C.9) and of (C.8) to (C.11), $m_A m_B$ in (C.20) becomes an operator m_{2op} operating on an internal function ξ_r^p,

$$\partial_I^{a\dot{b}}\partial_{II\dot{e}f}\chi_{\dot{b}}^{f}(x_I, x_{II})\xi_r^p\left(z_I^q, z_{IIs}\right) + (m_{2op} - \Phi_m(x_I, x_{II}))\psi_{\dot{e}}^{a}(x_I, x_{II})\xi_r^p\left(z_I^q, z_{IIs}\right) = 0 \quad \text{(C.23a)}$$

$$\partial_{I\dot{b}c}\partial_{II}^{d\dot{e}}\psi_{\dot{e}}^{c}(x_I, x_{II})\xi_r^p\left(z_I^q, z_{IIs}\right) + (m_{2op} - \Phi_m(x_I, x_{II}))\chi_{\dot{b}}^{d}(x_I, x_{II})\xi_r^p\left(z_I^q, z_{IIs}\right) = 0 \quad \text{(C.23b)}$$

z_I and z_{II} are associated with the quark and antiquark, respectively, just like x_I and x_{II} do. They are hidden independent variables (Section C1). Therefore, The meson wave Equations (C.23) and (C.21) (Hoh, 2005) are on level Logic2 of Section 2.2.

The choice of m_{2op} is, similar to (C.5), of the simplest form and is

$$m_{2op} = m_{1op} m_{1op}^*, \quad m_{1op} = m_{1op}^* = \sum\nolimits_q m_q \left(z_I^q \frac{\partial}{\partial z_I^q} + z_{II}^q \frac{\partial}{\partial z_{II}^q} + c.c \right) \tag{C.24}$$

m_{op} in (C.5) can be replaced by m_{1op} in (C.24) without affecting (C.4). This simple product form is approximate and needs be refined. The simplest choice of $\xi_r^p(z_I^q z_{IIs})$ is analogously to combine the first of (C.5) with (C.12). Let ξ_r^p be the octet part, to be associated with the octet mesons, in the decomposition $\underline{3} \times \underline{3}^* = \underline{1} + \underline{8}$, it then constitutes the basis vectors that generate the regular representation of the group of global SU(3) transformations.

The leaps here, i.e., departures from the BS equation (C.13) in Section 4.3, orignate in domain Logic. The introduction of the internal space z in Section C1 is necessitated by the requirement that the particle mass and momenta, being both observables, should be put on equal footing. The use of (C.6) is equivalent to the use of (C.2). The choice of scalar interaction in (C.15) and (C.16) is the simplest one, following Ed of Section A3, and also takes place in domain Logic. In this domain, this leap can be considered as choosing (one of) the simplest form of coupling between the mathematical systems (C.6) and (C.8). The recent mathematical requirements obtained when the relevant content in *Recent data* in Section 4.3 are taken across the boundary Logic-Physics, i.e., no free quark or diquark exists, are satisfied in (C.23) and (C.21). Thus, CR1 is fulfilled.

An alternative viewpoint is to discard the BS equation as an existing theory for hadrons. Then there is no conflict in Section 4.3 and CR1 does not apply, similar to the cases Section *3.2.3*.

C6. Baryon Wave Equations

The above procedure can analogously be applied to baryons. Here, the problem is greatly simplified for ground state baryons which have been successfully classified by considering them to consist of a quark and a diquark. Let the subscript *II* refer to the diquark, the corresponding baryon wave equations read (Hoh, 1993, 1994).

$$\begin{aligned}
&\partial_I^{a\dot{b}} \partial_I^{g\dot{h}} \partial_{II\,\dot{e}f} \chi^f_{\{\dot{b}\dot{h}\}}(x_I, x_{II}) \xi^{\{ps\}q}\left(z_I^r, z_{II}^t\right) \\
&\quad = -i(m_{3op} + \Phi_b(x_I, x_{II}))\psi_{\dot{e}}^{\{ag\}}(x_I, x_{II}) \xi^{\{ps\}q}\left(z_I^r, z_{II}^t\right) \\
&\partial_{I\,\dot{b}c} \partial_{I\,\dot{h}k} \partial_{II}^{d\dot{e}} \psi_{\dot{e}}^{\{ck\}}(x_I, x_{II}) \xi^{\{ps\}q}\left(z_I^r, z_{II}^t\right) \\
&\quad = -i(m_{3op} + \Phi_b(x_I, x_{II}))\chi^d_{\{\dot{b}\dot{h}\}}(x_I, x_{II}) \xi^{\{ps\}q}\left(z_I^r, z_{II}^t\right) \\
&\Box_I \Box_I \Box_{II} \Phi_b(x_I, x_{II}) = \frac{1}{4} g_s^6 \left\{ \chi^f_{\{\dot{b}\dot{h}\}}(x_I, x_{II}) \psi_f^{\{\dot{b}\dot{h}\}}(x_I, x_{II}) + c.c. \right\} \\
&m_{3op} = (m_{1op})^3
\end{aligned} \tag{C.25}$$

C7. Origin and Status of SSI

The simple product form of the last line is likewise approximate and needs be refined. The quark wave functions in (C.15–C.16) have been used as "scaffolding" in constructing the hadron wave Equations (C.23), (C.21) and (C.25) and are removed afterwards. It may seem that these equations have been arrived in ad-hoc ways. This is indeed the case. However, recall that all the operations in this Appendix take place in domain Logic and are completely free from restraint apart from self-consistency. Acceptance of these equations is solely based upon the test results. These results are obtained by mathematical manipulations of these equations on level Logic2 so that they can be moved to level Logic1, level Logic0 and finally across the boundary Logic-Physics in Fig. 1 into domain Physics, where they become new theories and are tested by contents (PDG data) from level Data0. This is equivalent to the criteria Ec of Section A3, LPb in Section A2 and Section A1.

If the tests are successful, it makes no difference how ad-hoc or odd the above construction processes of these equations may seem. In this case, one can in principle discard all the steps leading to (C.21), (C.23) and (C.25) and imagine that they have been dreamt up or conferred on as revelation. This is not different from that students accept the Newton and Schrödinger equations because they have been successfully tested, irrespective of the ways these equations were arrived at.

Equations (C.21), (C.23) and (C.25) for mesons and baryons, if right, play the same role as the one played by Dirac's equation for atoms. The strong interaction part resides largely in functions dependent upon the hidden indedendent variables, the relative space x and z_I and z_{II}, and is at first aimed at low energy phenomena not successfully covered by QCD. Introducing local phases into the X dependent part of the wave functions leads to massive $W^{\pm}$ and Z gauge bosons without any Higgs boson.

Confinement arises naturally from (C.21) and the third of (C.25) as a result of their higher order nature. The role of Higgs bosons is taken over by the kaons or pions by virtue of the presence of the relative time x^0 among the quarks. Ground state meson spectra and some meson decay problems involving weak, electromagnetic and strong interactions have been rather successfully treated. Thus, the Dalitz slope parameters in $K \rightarrow 3\pi$ have been largely correctly predicted (Hoh, 2005). Further applications are presently hampered by mathematical complexities.

While the rest frame ground state meson wave functions have been found in closed form, baryons wave functions have not yet been obtained due to mathematical difficulties associated with the higher order equations. Assuming the existence of such functions, the baryon magnetic moments are largely correctly predicted. Further, angular momentum is found to be not conserved in free neutron decay (Hoh, 2005).

Recently, this assumption has been substantiated and baryon wave functions have been obtained numerically as eigensolutions to these differential equations.

SSI has however not been treated at high energies. Also, quantization of SSI has not been investigated; the hidden independent variable aspects of SSI renders that the conventional procedures in quantizing nonlocal theories, which led to difficulties, need be reaccessed.

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