

FIELD THEORY

Predrag Cvitanovic

(lecture notes prepared by Ejnar Gyldenkerne)

TO MY GIRLS

CONTENTS:

| | | |
|----|------------------------------|----|
| | PREFACE | 3 |
| 1. | INTRODUCTION | 4 |
| | A. Land of Quefithe | 6 |
| 2. | GENERATING FUNCTIONALS | 9 |
| | A. Propagators and vertices | 9 |
| | B. Green functions | 10 |
| | C. Dyson-Schwinger equations | 12 |
| | D. Combinatoric factors | 13 |
| | E. Generating functionals | 15 |
| | F. Connected Green functions | 18 |
| | G. Free field theory | 20 |
| | H. 1PI Green functions | 20 |
| | I. Vacuum bubbles | 25 |
| | J. Summary | 30 |
| 3. | PATH INTEGRALS | 33 |
| | A. A Fourier transform | 33 |
| | B. Gaussian integrals | 34 |
| | C. Wick expansion | 36 |
| | D. Tree expansion | 38 |
| | E. Legendre transformations | 40 |
| | F. Saddlepoint expansion | 40 |
| | G. Point transformations | 44 |
| | H. Summary | 45 |
| 4. | FERMIONS | 47 |
| | A. Pauli principle | 47 |
| | B. Anticommuting sources | 49 |
| | C. Fermion arrows | 51 |
| | D. Fermionic path integrals | 54 |
| | E. Fermionic determinants | 55 |
| | F. Fermionic jacobians | 57 |
| | G. Summary | 58 |

| | | |
|----|---|-----|
| 5. | SPACETIME PROPAGATION | 61 |
| | A. Free propagation | 61 |
| | B. A leap of faith | 66 |
| | C. Scattering matrix | 67 |
| 6. | FROM GHOULIES TO GHOSTIES | 71 |
| | A. Massless vector particles | 71 |
| | B. Photon propagator | 74 |
| | C. Colored quarks | 76 |
| | D. Compton scattering | 77 |
| | E. Color algebra | 78 |
| | F. Three-gluon vertex | 79 |
| | G. Ghosts | 84 |
| | H. Four-gluon vertex | 85 |
| | I. QCD action | 88 |
| | J. Summary | 91 |
| 7. | QCD WARD IDENTITIES | 93 |
| | A. Ward identities for full Green functions | 93 |
| | B. Examples of Ward identities | 96 |
| | C. Becchi-Rouet-Stora identities | 97 |
| | APPENDICES | 101 |
| | A. 2-particle irreducibility | 101 |
| | B. Solution to the "find 7 errors" problem | 109 |
| | C. Some popular gauges | 113 |
| | D. Feynman rules for QCD | 115 |

PREFACE

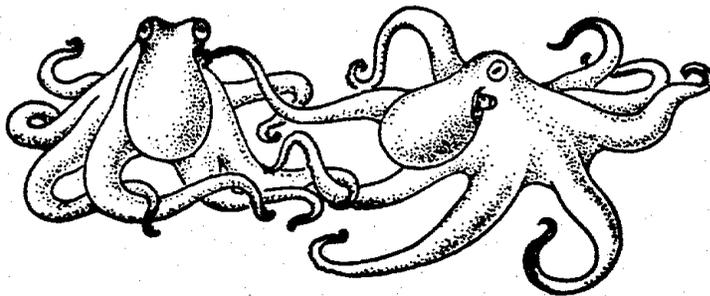
In the fall of 1979, Benny Lautrup and I set out to write the ultimate Quantum Chromodynamics review. The report was going to consist of four parts, one for each line of

*From Ghoulies and Ghosties
and Long-leggety Beasties
and Things that go bump in the Night
Good Lord, deliver us!*

Ghoulies are body-snatchers and grave robbers; they are those revel in that which is revolting.~

Benny had previously described ghosties in a very nice set of QCD lectures^t which we were going to use as the first part. Green functions resemble long-leggety beasties; they, and the general formalism of field theory, were to be developed in the second part. The things that go bump in the night are clearly the many unpleasant surprises of field theory; divergences, together with the regularization and computation techniques, were to be covered in the third part. Finally, good Lord deliver us, we were going to actually calculate a few basic QCD integrals.

Well, while I was lecturing about the long-leggety beasties, Benny deserted me for lattice, and the ultimate QCD review was never written. That these lectures appear at all is largely due to tireless work by Ejnar Gyldenkerne and to the criticisms of the QCD study group at the Niels Bohr Institute. In writing these lectures I have profited much from discussions with Benny Lautrup, to **whom** I direct my thanks.



tB. Lautrup, "Of ghoulies and ghosties - an introduction to QCD", Basko Polje 1976 lectures, available as Niels Bohr Institute preprint NBI-HE-76-14.

Critics say:

... Seen in [Cvitanovic's] framework, field theory books are like every other fonn in the universe: they are generated by changing intervals of tension between a dominant system and a competing system in a space-time continuum that is dependent on the process of competition between these two stabilities and not on any General Concept of Space and Time ... [Cvitanovic's] method thus valorizes the microcosm which illuminates macroc'-ic fonn by the high tendency of microcosmic patterns to, peat themselves and so greatly limit structural variailon in the macrocosm ... But on another level, as in the sagas, the Song of Rolland, the Jliad, the Odyssey, the Nibelun/enlied, the Aeneid and Beowulf, the real dynamic focus o the book is the power of anger.

Patricia Harris Stablein

A distinguished reviewer says:

**IT IS NOT
EVEN WRONG**



*El noble
cigarro*