É. V. Shuryak. *The quark-gluon plasma.* This paper deals with a state of matter in which the density and/or temperature are so high that ordinary particles—nucleons, pions, etc.—dissociate into their components—quarks and gluons. By virtue of the strong similarity to the ordinary electrodynamic plasma, this phase of matter has come to be known as the *quark-gluon plasma*; see the review in Ref. 1.

Theoretical and experimental study of this state is important not only for specific applications (collisions of high-energy particles, multiquark systems, neutron stars, cosmology), but chiefly for better understanding of the main object of the theory: the QCD *physical vacuum*, which is an extremely complex medium consisting of nonperturbative field fluctuations.

The so-called *instantons*—nontrivial topologic solutions of the field equations[2]—are an important example of these fluctuations. Valuable information on the properties of the physical vacuum can be obtained within the framework of the QCD *sum-rule* method[3], which relates them to observable hadron properties. Comparison of these approaches led Shuryak[4] to a "*grainy-vacuum*" picture that includes, in addition to soft fluctuations with dimensions of the order of 1 Fm, harder fluctuations of instanton nature with a radius of about 1/3 Fm. Although they occupy only about 1/20 of space-time, they dominate in the known vacuum averages.

This picture of the vacuum has made it possible to explain a number of facts pertaining to hadron structure, including the existence of a hadron substructure in the form of so-called "component" quarks, also with sizes of the order of magnitude of 1/3 Fm.

There are at least two phase transitions in superdense matter: "freeing of color"[5] and restoration of chiral symmetry, i.e., vanishing of the quark condensate. It was shown in Ref. 4 that the latter is accompanied by a finite jump in the amount of condensate at the transition point.

Analysis of the macroscopic systems enables us to make certain statements regarding multiquark resonances. Data on neutron stars practically preclude[1] their existence if they consist only of u-, and d-quarks. Admixture of heavier s, c...-quarks changes the situation, and states with *arbitrarily large* numbers of quarks are possible in principle. Data on q^2q^2-mesons and q^6-dibaryons are in qualitative agreement with this statement.

The central problem of the theory of collisions of high-energy particles is that of the *validity of the macroscopic approach* for description of the resulting excited system. To diagnose the initial, hotter stages of a collision, it is necessary to use "penetrating" radiation in the form of γ, e^+e^-, etc.,[6] or radiation from the surface. Studies[7] of spectra in the range $p_\perp = 1-4$ GeV/c enable us to answer the above question in the affirmative: up to proton energies of the order of magnitude of 1 TeV (in the laboratory system), mixing is quite rapid and an approximately (locally) equilibrium plasma forms. Collisions of heavy nuclei with energies of the order of magnitude of 10–100 GeV per nucleon would be a more appropriate object for these studies.

[1] E. V. Shuryak, Phys. Rept. **61C**, No. 2 (1980).
[2] A. A. Belavin, A. M. Polyakov, A. A. Schwartz, and Yu. S. Tyupkin, Phys. Lett. Ser. B **59**, 85 (1975).
[3] M. A. Shifman, A. I. Vainshtein, and V. I. Zakharov, Nucl. Phys. Ser. B **147**, 385, 448, 519 (1979).
[4] E. V. Shuryak, Phys. Lett. Ser. B **107**, 103 (1981); The Role of Instantons in QCD: Preprints of Institute of Nuclear Physics, 81-118, 81-134, 82-3; Nucl. Phys. Ser. B **203**, 93, 116, 140 (1982).
[5] A. M. Polyakov, Phys. Lett. Ser. B **72**, 477 (1978). L. Susskind, Phys. Rev. Ser. D **20**, 2610 (1979).
[6] E. L. Feĭnberg, Izv. AN SSSR, Ser. Fiz. **26**, 622 (1962).

[7]É. V. Shuryak, Yad. Fiz. **28**, 796 (1978) [Sov. J. Nucl. Phys. **28**, 408 (1978)]; Phys. Lett. B **78**, 150 (1978); O. V. Zhirov, Yad. Fiz. **30**, 1098 (1979) [Sov. J. Nucl. Phys. **30**, 571 (1979)].