The Response of Peritoneal Tissue to Industrial Dusts

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THE RESPONSE OF PERITONEAL TISSUE TO INDUSTRIAL DUSTS[1]

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The reaction of the peritoneal tissue to injected dusts has been described in previous reports[3] and attention has been called to the possibility of using the results of such a biological response to predict the pneumoconiosis-producing potentialities of industrial dusts. From time to time, minor modifications in the method of introducing the dusts into the animals have been made to simplify the procedure without altering the results.

As now practiced, the test is briefly as follows: Two cubic centimeters of a 5-percent suspension of air-elutriated (or 325-mesh screened), heat-sterilized dust in sterile, physiological saline solution is injected into the peritoneal cavities of a number of guinea pigs. Animals are killed and examined 14, 45, and 90 days after injection (in earlier experiments at intervals up to 1 year). The nodules produced by the dust on the anterior abdominal walls or in the omentum at the various intervals are compared. The gross appearance is usually sufficient for interpretation of results.

Three general types of reaction are produced by the various dusts. These have been designated as absorptive, proliferative, and inert.

Dusts of the absorptive group produce nodules which progressively decrease in size as the interval between injection and examination increases. Eventually the dust disappears from the peritoneal tissue.

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[1] From the Division of Industrial Hygiene, National Institute of Health.

[2] Director of the Bureau of Mines.

[3] Miller, J. W., and Sayers, R. R.: The response of peritoneal tissue to dusts introduced as foreign bodies. Pub. Health Rep., 49: 80-89 (January 19, 1934) (Reprint No. 1606). J. Am. Med. Assoc., 103: 907-912 (September 22, 1934). Am. J. Pub. Health, 25: 452-456 (April 1935). Pub. Health Rep., 51: 1677-1689 (December 4, 1936) (Reprint No. 1787).

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Microscopically, a typical early nodule consists of a mass of the dust mixed with fine, granular, necrotic material. A zone of fibroblasts with an occasional macrophage surrounds this more or less centrally placed mass. With time the necrotic material becomes less and finally disappears. Brown pigment particles, apparently of endogenous origin, are usually found rather early, and in an experiment of a year's duration are the only evidence that the dust was introduced into the peritoneal cavity.

Dusts causing a proliferative type of reaction produce nodules which progressively increase in size as the interval between injection and examination increases. The maximum growth, using a 0.1-gm. dose for each guinea pig, is reached in about 90 days. Microscopically the nodules 7 days after injection are similar to those produced by the dusts of the absorptive group. As the process continues, the fibroblasts in the cellular zone about the central mass of dust and necrotic material are largely replaced by macrophages which are usually filled with dust particles. This is most marked in the 30-day series. Later, the engulfed dust particles appear to decrease in numbers and fibroblasts and adult connective tissue cells predominate. The area of necrotic material persists throughout the duration of the test. After 90 days fat cell formation in the cellular zone and calcification of the necrotic material is noted. All of the dusts classified in this group studied thus far are various forms of naturally occurring silica.

The nodules produced by the inert group of dusts are, in the early stages, grossly similar to those of the other two groups. As the interval between injection and examination increases the nodules become flattened with irregular edges, and numerous dispersed particles are present in the adjacent peritoneum. These are often found a considerable distance from the original nodules. The amount of dust found in the peritoneal cavity 1 year after injection is essentially the same as noted in 7 days. Histologically, the fibroblast is the early predominating cell. An increase in macrophages is noted at the 30-day interval and eventually fibrous tissue and accompanying fat cells predominate. No necrosis is noted at any interval in the entire process. The response is characteristic of that caused by a nonirritating foreign body.

It has been possible to correlate the response of peritoneal tissue to certain dusts with the results of X-ray examination or of post-mortem study of workers exposed by inhalation to high concentrations of the same dusts for protracted periods of time. These records are far from complete, because medical and roentgenographic surveys are available for only a limited number of the dusty trades. Nevertheless, the preliminary results of such comparisons can be summarized: (*a*) No cases of pneumoconiosis have been reported and confirmed among workers exposed solely to dusts of the absorptive group; (*b*) all of the dusts so far examined that fall into the proliferative group are known to produce a nodular, pulmonary fibrosis (silicosis); (c) pneumoconioses caused by dusts of the inert group (asbestos,[4] anthracite mine dusts,[5] bisque ware,[6] mica,[7] pyrophyllite,[8] and talc[9]) have been reported as a result of X-ray examination of industrial workers. Where autopsy material is available, certain of the dusts of this group are known to produce a diffuse, interstitial, pulmonary fibrosis, or a mixed nodular and diffuse fibrosis, such as is produced by anthracite coal containing free silica.

Interpretation of the response produced by a dust in the peritoneal tissue in animals can be used as an index to determine the potential harmfulness of an industrial dust to which workers are exposed. Thus, an absorptive reaction can indicate that the dust is relatively harmless, while a proliferative response would indicate the dust to be definitely harmful. The dusts producing an inert reaction have been considered as less hazardous than those producing a proliferative reaction, and more dangerous than those of the absorptive group. The intraperitoneal method of studying the physiological action caused by dusts is not applicable to highly toxic material, a sublethal dose of which is too small to be grossly visible in the peritoneal tissue, or to dusts that are readily soluble.

The following dusts have been examined by this method and the results, with pertinent identifying data, are given below.

DUSTS CAUSING AN ABSORPTIVE REACTION

Calcite.—A pure mineral dust. Chemical analysis: Acid insoluble matter, 0.0 percent; silica, 0.0 percent. Petrographic examination: A calcite of high purity.

Calcite.—A pure mineral dust. Chemical analysis: Acid insoluble matter, 0.1 percent, all of which was silica. Petrographic examination: A calcite of high purity.

Precipitated calcium carbonate.—A chemical byproduct. An industrial dust. Chemical analysis: Silica, 0.4 percent; calcium carbonate, 87.9 percent; magnesium carbonate, 10.1 percent; magnesium oxide, 0.1 percent; iron and aluminum oxides, 0.6 percent. Petrographic examination: Precipitated calcium carbonate, about 98 percent; crystals, probably sodium carbonate, about 2 percent.

Gypsum.—The uncalcined, natural mineral. An industrial dust. Chemical analysis: Silica, 1.3 percent; calcium sulfate, 97.1 percent. Petrographic examination: Gypsum, about 70 percent; calcite, about 30 percent.

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Limestone.—An industrial dust. Chemical analysis: Silica, 1.5 percent; calcium oxide, 54.4 percent; magnesium oxide, 0.4 percent; iron and aluminum oxides, 0.4 percent. Petrographic examination: Irregularly rounded calcite. No impurities noted.

Limestone.—An industrial dust. Chemical analysis: Silica, 2.73 percent; calcium carbonate, 95.21 percent; magnesium carbonate, 1.17 percent. Petrographic examination: A dolomitic limestone. No impurities observed.

Limestone.—An industrial dust. Chemical analysis: Acid insoluble matter, 7.2 percent; silica, 5 percent. Petrographic examination: Only an infrequent quartz crystal was noted. A high calcium carbonate content.

Limestone.—An industrial dust. Chemical analysis: Silica, 11.7 percent; calcium carbonate, 81.7 percent; magnesium oxide, 3.4 percent; ferric oxide, 1.4 percent; aluminum oxide, 1.5 percent. Petrographic examination: About 10 percent quartz and about 90 percent calcite.

Portland cement.—An industrial dust. Chemical analysis: Silica, 21.1 percent; calcium oxide, 74.4 percent; magnesium oxide, 2.8 percent. Petrographic examination: Normal portland cement.

Pyrolusite.—An industrial dust. Chemical analysis: Manganese, 54.9 percent. Petrographic examination: No quartz observed. This material was much more slowly absorbed than the others given here.

DUSTS CAUSING A PROLIFERATIVE REACTION

Bisque ware.—An industrial dust. Ground semivitreous pottery bisque ware, fired at a relatively low temperature. Chemical analysis: Silica, 72.0 percent. Petrographic examination: Quartz, about 40 to 50 percent. The remainder is semifused clay and feldspar.

Chert.—An industrial dust. Chemical analysis: Total silica, 76.1 percent. Petrographic examination: Quartz and chert, about 60 percent (about 25 percent of the silica is normal quartz). Calcite, about 40 percent.

Diatomite.—An industrial dust. Chemical analysis: Silica, 92.5 percent; aluminum oxide, 3.5 percent; ferric oxide, 1.5 percent; calcium oxide, 0.4 percent; magnesium oxide, 0.7 percent. Petrographic examination: Pure diatomite. No quartz or calcite present.

Greenware.—An industrial dust. Ground semivitreous, unfired pottery ware. Chemical analysis: Silica, 69.0 percent. Petrographic examination: Quartz, about 50 percent; feldspar, about 15 percent; clay, about 35 percent.

Greenware.—An industrial dust. Ground vitreous, unfired pottery ware. Petrographic examination: Higher quartz and less feldspar than the above. Clay, about the same amount.

Porcelain enamel frit.—An industrial dust. Chemical analysis: Silica, 35 to 50 percent; the remainder is oxides of antimony, zinc, and aluminum, and fluorides of sodium, aluminum, and calcium. Analysis varies within the above silica limits.

Quartz.—A pure mineral dust. Chemical analysis: Silica, 99.4 percent. Petrographic analysis: Normal crystalline quartz of high purity.

Quartz.—A pure mineral dust. Chemical analysis: Silica, 99.3 percent. Petrographic examination: Normal crystalline quartz of high purity.

Quartz.—An industrial dust. Chemical analysis: Silica, 99.1 percent. Petrographic examination: Normal quartz.

Quartz.—An industrial dust. Petrographic examination: Normal crystalline quartz of high purity.

Quartz.—An industrial dust. Identical with the above sample but treated with 0.6 percent crude pine fatty acids.

Quartz-sericite.—The source of this dust is not known. Chemical analysis: Total silica, 81.04 percent; calcium oxide, 0.30 percent; magnesium oxide, 0.45 percent; sodium oxide, 0.10 percent; potassium oxide, 0.98 percent; iron oxide, 0.25 percent; aluminum oxide, 14.26 percent; total water, 2.61 percent. Petrographic examination: Quartz, about 50 percent; muscovite (variety, sericite), about 45 percent; fibrous sericite, less than 5 percent.

Tripoli.—An industrial dust. Chemical analysis: Total silica, 98.9 percent; calcium oxide, 0.2 percent; magnesium oxide, 0.1 percent; iron and aluminum oxides, 0.3 percent. Petrographic examination: Chalcedonic silica (crystalline aggregates) with an occasional crystal of normal quartz.

DUSTS CAUSING AN INERT REACTION

Aluminum.—Pure aluminum bronzing powder of the finest grade. Chemical analysis: Aluminum oxide, 11.0 percent.

Alundum.—An industrial dust. Chemical analysis: Silica, 4.6 percent; aluminum oxide, 88.4 percent; ferric oxide, 6.9 percent. Petrographic examination: Well crystallized, artificial alumina.

Asbestos (amosite).—An industrial dust. Chemical analysis: Total silica, 48.31 percent; calcium oxide, 0.48 percent; magnesium oxide, 0.66 percent; sodium oxide, 0.72 percent; potassium oxide, 0.02 percent; iron oxide, 44.22 percent; combined oxides, 46.37 percent; total water, 3.62 percent. Petrographic examination showed predominating individual fibers and about 1 or 2 percent of dolomite.

Asbestos (chrysotile).—An industrial dust. Chemical analysis: Total silica, 37.52 percent; calcium oxide, 2.00 percent; magnesium oxide, 35.85 percent; sodium oxide, 0.54 percent; potassium oxide, 0.08 percent; iron oxide, 7.70 percent; combined oxides, 10.30 percent; total water, 12.86 percent. Petrographic examination: Serpentine, in part chrysotile, about 85 percent; dolomite, about 5 percent; magnetite and (or) chromite, about 5 percent; talc, less than 5 percent.

Asbestos (crocidolite).—An industrial dust. Chemical analysis: Total silica, 50.86 percent; calcium oxide, 0.68 percent; potassium oxide, 0.08 percent; iron oxide, 38.33 percent; combined oxides, 39.03 percent; total water, 5.02 percent. Petrographic examination showed fibrous material only.

Anthracite coal.—An industrial dust. Chemical analysis: Ash, 12.6 percent; silica, 6.6 percent. Petrographic examination: Coal about 95 percent; inorganic material, about 5 percent. About 60 percent of the inorganic material is quartz; about 40 percent is calcite, with an occasional crystal of rutile.

Anthracite coal.—An industrial dust. Chemical analysis: Ash, 16.0 percent; silica, 8.6 percent. Petrographic examination: Coal, about 95 percent; inorganic material, about 5 percent. About 95 percent of the inorganic material is quartz; about 5 percent is calcite, siderite, limonite, and rutile.

Bentonite.—An industrial dust. Petrographic examination: Clay, variety montmorillonite, about 97 percent; feldspar, about 2 percent; quartz, none observed.

Bisque ware.—An industrial dust. Ground vitreous pottery bisque ware, fired at a relatively high temperature. Petrographic examination: Quartz, about 30 to 40 percent. The particles are wholly or partially covered by the glass phase. This is absent in the semivitreous bisque ware.

Bituminous coal.—An industrial dust. Chemical analysis: Ash, 8.5 percent; silica, 0.8 percent. Petrographic examination: Mineral content (calcite), about 1 to 2 percent.

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Bituminous coal.—An industrial dust. Chemical analysis: Ash, 8.0 percent; silica, 3.5 percent. Petrographic examination: Mineral content (quartz, calcite, clay), between 1 and 3 percent.

Calcium phosphate.—An industrial dust. Chemical analysis: Calcium phosphate, 75.38 percent; calcium carbonate, 3.98 percent; calcium fluoride, 6.80 percent; magnesium carbonate, 0.51 percent; iron oxide, 3.08 percent; aluminum oxide, 3.12 percent; free silica, 2.70 percent; combined silica, 1.87 percent. Petrographic examination: Earthy phosphates (not apatite), about 97 percent; normal and chalcedonic quartz, about 3 percent.

Chromite.—An industrial dust. Chemical analysis: Silica, 7.8 percent; chromic oxide, 25.0 percent. Petrographic examination: Quartz, less than 5 percent.

Diamond dust.—An industrial dust. Pure bortz diamond dust used as abrasive. Petrographic examination confirms identity.

Feldspar.—Chemical analysis: Total silica, 65.9 percent; calcium oxide, 0.81 percent; magnesium oxide, 0.10 percent; aluminum oxide, 19.55 percent; iron oxide, 0.23 percent; potassium oxide, 8.98 percent; sodium oxide, 3.18 percent. Petrographic examination: Feldspar (plagioclase-microcline), about 95 percent; normal quartz, about 5 percent.

Fuller's earth.—An industrial dust. Filtral clay. Chemical analysis: Silica, 55.7 percent; free silica (estimated), 1.0 percent; water, 15.9 percent. Petrographic examination: Clay and residual decomposing feldspar, about 95 percent; quartz, less than 1 percent; gypsum, less than 5 percent.

Fuller's earth.—An industrial dust. Chemical analysis: Silica, 56.4 percent; free silica (estimated), 7.0 percent; water, 8.5 percent. Petrographic examination: Clay and decomposing feldspar, about 90 to 95 percent; quartz, about 5 to 10 percent.

Fuller's earth.—An industrial dust. Chemical analysis: Silica, 57.9 percent; ferric oxide, 2.5 percent; aluminum oxide, 13.1 percent; calcium oxide, 2.9 percent; magnesium oxide, 8.5 percent; water, 6.7 percent. Petrographic examination: Clay-like masses, rounded and irregular, about 70 percent; quartz, about 15 percent; dolomite, about 15 percent.

Fuller's earth.—An industrial dust. Filtral clay. Chemical analysis: Silica, 62.1 percent; free silica (estimated), 3.0 percent; water, 14.9 percent. Petrographic examination: Clay and residual decomposing feldspar, about 98 percent; quartz, 1 to 2 percent; feldspar, an occasional fragment.

Glass wool.—An industrial dust. Finely ground sample of commercial hard glass wool was used. No chemical or petrographic examinations were thought necessary.

Hematite (jewelers' rouge).—An industrial dust. Chemical analysis: Total silica, 1.5 percent; iron oxide, 98.3 percent. Petrographic examination showed no impurities.

Kaolin.—An industrial dust. Petrographic examination: China clay and hydromica predominant; quartz and feldspar, a trace.

Lanthanum sublimate.—An industrial dust. From the burning of white flame electrodes. Chemical analysis: Lanthanum, 40.0 percent. Petrographic examination: Particles too small to identify.

Mica.—An industrial dust. Chemical analysis: Silica, 46.92 percent; magnesium oxide, 0.86 percent; aluminum oxide, 34.95 percent; ferric oxide, 2.65 percent; potassium oxide, 9.54 percent; sodium oxide, 1.02 percent; manganese dioxide, trace. Petrographic examination: Mica, both as plates and fibers, plates predominating, about 98 percent. A very small amount of quartz and feldspar.

Precipitator ash.—An industrial dust. Chemical analysis: Total silica, 49.86 percent; calcium oxide, 6.03 percent; magnesium oxide, 3.01 percent; iron and aluminum oxides, 40.46 percent. Petrographic examination: Loosely consolidated, white, soft, grit-free ash, about 40 percent; partly rounded aggregates of semifused ash, about 45 percent; smooth fused glass globules, about 10 percent; normal quartz fragments, about 5 percent; unburned coal, less than 1 percent.

Precipitator ash.—An industrial dust. From the boiler plant of a coal company. Chemical analysis: Silica, 48.2 percent; aluminum oxide, 29.3 percent; ferric oxide, 8.5 percent; calcium oxide, 2.1 percent; magnesium oxide, 0.1 percent; organic matter, 8.6 percent. Petrographic examination: Predominantly spherulized glass, some coal fragments, and a trace of quartz.

Precipitator ash.—An industrial dust. Chemical analysis: Silica, 48.3 percent; aluminum oxide, 29.4 percent; ferric oxide, 8.6 percent; calcium oxide, 1.8 percent; magnesium oxide, 0.4 percent; organic matter, 8.7 percent. Petrographic examination: Predominantly semivitrified ash particles, some spheres, coal, and a trace of quartz.

Precipitator ash.—An industrial dust. Chemical analysis: Total silica, 44.7 percent; moisture, 0.1 percent. Petrographic examination: Mostly spherical fused-glass particles, with some semifused masses of crystallites, quartz, possibly calcite and coal fragments.

Precipitator ash.—An industrial dust. Lamphouse deposit from the burning of carbon arcs. Chemical analysis: Rare earth oxides (cerium group), 70.7 percent; ferric oxide, 0.8 percent; magnesium oxide, 0.5 percent; moisture, 9.8 percent; silica, none. Petrographic examination: Inorganic material, rudely rounded, about 5 percent of opaque carbonaceous material and no quartz.

Precipitator ash.—An industrial dust. Condensate from the flue system from burning of carbon arcs. Chemical analysis: Rare earth oxides (cerium group), 59.5 percent; silica, 1.0 percent; ferric oxide, 4.1 percent; magnesium oxide, 0.9 percent; calcium oxide, 0.6 percent; ignition loss, 18.4 percent. Petrographic examination: No quartz or calcite, otherwise similar to preceding sample.

Pyrophyllite.—An industrial dust. No chemical analysis obtained. Petrographic examination: Predominantly pyrophyllite, with a small amount of rutile and some quartz. The quantity of quartz was hard to estimate.

Rock wool.—An industrial dust. A finely ground sample of commercial, insulating rock wool.

Selenium.—An industrial dust. Chemical analysis: Selenium, 98.8 percent; tellurium, 0.01 percent; ash, 1.16 percent.

Selenium.—A chemically prepared sample of highest purity.

Sericite.—A pure mineral dust. Chemical analysis: Total silica, 51.74 percent; calcium oxide, 0.61 percent; magnesium oxide, 1.74 percent; sodium oxide, 3.40 percent; potassium oxide, 4.48 percent; iron oxide, 5.83 percent; combined oxides, 31.82 percent; total water, 6.26 percent. Petrographic examination: Sericite and feldspar residues (fibrous sericite predominates), about 95 percent; quartz, less than 5 percent.

Shale.—An industrial dust. Chemical analysis: Silica, 61.0 percent; aluminum oxide, 12.4 percent; calcium oxide, 4.5 percent; ferric oxide, 5.0 percent; magnesium oxide, 1.3 percent; sodium oxide, 2.3 percent; potassium oxide, 1.5 percent; moisture, 10.3 percent. Petrographic examination: About 35 percent quartz. The majority of the particles appear to be coated with clay.

Silicon carbide.—Pure manufactured silicon carbide. Chemical analysis: Silicon, 67.5 percent. Petrographic examination showed no impurities.

Soapstone.—An industrial dust. Chemical analysis: Total silica, 49.9 percent; calcium oxide, 1.7 percent; magnesium oxide, 26.2 percent. Petrographic examination: Talc, as plates or fibrous splinters, about 65 percent; tremolite, as long fibrous crystals, about 30 percent; dolomite, about 5 percent.

Soapstone.—An industrial dust. Chemical analysis: Total silica, 38.8 percent; calcium oxide, 5.0 percent; magnesium oxide, 22.7 percent. Petrographic examination: Talc, about 55 percent; dolomite, about 30 percent; tremolite, about 15 percent. No quartz observed.

Talc.—An industrial dust. Chemical analysis: Total silica, 49.0 percent; calcium oxide, 8.8 percent; magnesium oxide, 22.6 percent. Petrographic examination: Tremolite, about 60 percent; talc, about 40 percent.

Talc.—An industrial dust. Chemical analysis: Total silica, 56.54 percent; calcium oxide, 6.25 percent; magnesium oxide, 30.74 percent; calcium silicate, 11.00 percent; calcium carbonate, 1.88 percent; iron and aluminum oxides, 1.04 percent; ignition loss, 4.60 percent. Petrographic examination: Talc, mostly fibrous, about 75 percent; tremolite, partly altered to talc, about 25 percent; calcite and (or) dolomite, about 1 percent.

Titanium oxide.—An industrial dust. A finely divided high purity sample.

Sodium silicate.—A laboratory prepared sample containing 1 part sodium oxide to 3.1 parts silica. Higher ratios of sodium oxide kill the animals.

Trap rock.—An industrial dust. Chemical analysis: Silica, 51.7 percent; aluminum oxide, 16.0 percent; ferric oxide, 2.0 percent; ferrous oxide, 9.9 percent; calcium oxide, 10.0 percent; magnesium oxide, 6.2 percent. Petrographic examination: Feldspar, some slightly decomposed, about 45 percent; pyroxene, about 45 percent; magnetite, about 10 percent; biotite, about 1 percent.

Volcanic ash.—An industrial dust. Chemical analysis: Silica, 54.4 percent; aluminum oxide, 14.5 percent; ferric oxide, 3.8 percent; magnesium oxide, 2.6 percent; calcium oxide, 0.7 percent; ash, 78.2 percent. Petrographic examination: Fine volcanic ash partially altered to montmorillonite. No quartz observed.

Volcanic ash.—A specially treated sample. Chemical analysis: Silica, 74.2 percent; mixed oxides, 16.8 percent; ferric oxide, 2.2 percent; calcium oxide, 0.5 percent; magnesium oxide, 2.2 percent. Petrographic examination: Glass only. No quartz or calcite observed.

SUMMARY AND CONCLUSIONS

A definite quantity of dust injected into the peritoneal cavity of a guinea pig produces one of three types of reaction. It disappears, causes proliferation of the peritoneal tissue, or remains as an inert foreign body. These reactions may be used as a basis for the biological classification of industrial dusts, and seem to indicate that some relationship exists between the type of reaction produced in the peritoneal tissue by a dust and the ability of this dust to produce a characteristic type of pneumoconiosis. An absorptive reaction may indicate that a dust is relatively harmless, while a proliferative reaction, characteristic of quartz, may be associated with the ability to produce pulmonary fibrosis. Dusts of the inert group, that is, those that show a tendency to remain in the tissues, should be considered as potentially harmful, but not so dangerous as those causing a proliferative response.

With this biological method of classification, which in a number of instances has been correlated with clinical observations and industrial surveys, it is quite possible to determine the pneumoconiotic potentialities of a dust in a relatively short time, usually 60 days.

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