Biology of Cancer

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I BELIEVE THAT CANCER IS THE MOST challenging disease which confronts biological science. It involves the most basic phenomenon in biology, namely, growth. It is characterized by an abnormal, unlimited, unregulated growth of tissue which destroys the host which nourishes it. It is unique among diseases because the host is consumed by its own flesh. The thought of this fact, the frequently associated pain, and the insidiousness and treachery of its attack place cancer first among the most dreaded diseases.

The basic principles of cancer as a descriptive science were known to Galen (150 A.D.), who recognized three classes of tumors. The tumors of his third class were referred to as "tumors contrary to nature." They were called "contrary to nature" because of their abnormal and unregulated growth and frequently destructive character. There were two types, one benign and the other malignant; the latter was called "cancer."

About the middle of the 19th Century, when it became generally agreed that a cancer consisted of cells, two hypotheses regarding the nature of cancer received recognition. One maintained that normal cells can be transformed into cancer cells by irritation or infection of some type; the other, that the cells which form cancer were cancerous from embryonal life as the result of an hereditary blemish or an embryonal rest of cells excluded from the line of normal development.

These are the principal ideas contributed by the descriptive scientific approach to the problem of the cause of cancer. In addition much important and very valuable information which led to the morphologic classification and diagnosis of the disease was accumulated.

The descriptive science of cancer added nothing to the treatment of the disease, since therapeutics is entirely an experimental science. And, it is generally agreed that the cause of a disease remains a theory until established by controlled experimentation.

The study of cancer as an experimental science began just prior to the turn of the century, when cancer was first transplanted in laboratory animals by Hanau (1889) and Moreau (1891)—a fact which was soon confirmed by Leo Loeb (1901) and Jensen (1902). Since then, spontaneous cancer has been observed in almost all species of animals; cancer susceptibility has been bred into and out of animals; cancer has been produced by various types of chemical substances (carcinogens); and the chemotherapeutic action of hundreds of chemical compounds have been assayed on animals with transplanted tumors. This approach has contributed a mass of basic information to the problem of cancer. Moreover, all the knowledge, tools, and techniques of biology and medicine and of chemistry and physics have been focused on the problem. No known aspect has escaped some experimental attention. Many facts have been established, and a few optimistic experienced students of the problem believe that so much has been discovered in the last 20 years that the therapeutic control of advanced cancer is "just around the corner."

One of the most significant contributions of the last 25 years has been *the unequivocal proof* that cancer can be cured by removal or destruction if recognized early enough. But the grim and urgent problem is to prevent, cure, or control advanced cancer.

The most productive research for the treatment of advanced cancer, from the viewpoint of present applications, has been the development of the hormonal relationships to cancer of the prostate (*10*) and breast (*9*). This success clearly demonstrates that the most significant work to be done in the forseeable future is basic research, both experimental and descriptive. The currently sick must be cared for, of course; but we must look also toward the future saving of millions of lives.

The advances in the basic knowledge of cancer have not yet answered with certainty some of the fundamental biological questions.

What is the difference between a benign and a malignant tumor?

At present it is not possible to draw a clear line of distinction between a benign and a malignant tumor except to say that, when a benign tumor starts to invade and metastasize, it has undergone malignant transformation. That such may occur has been demonstrated experimentally, e.g. the Shope papilloma (*24*), and the papilloma induced with tar (*11*), and the clinical evidence is strongly presumptive (*27*).

Invasiveness and metastasis do not always signify that a tumor is a cancer or truly destructive of the host. For example, the chorionic villi (fetal part of the placenta) invade the endometrium (uterus) up to a stage of placental development and then act like a benign growth, even though the placental tissue has a carbohydrate metabolic pattern like malignant tissue (*7*). Also, during pregnancy chorionic cells enter the blood stream and lodge in the lungs, but they do not form tumors there. The chorioadenoma extensively invades the wall of the uterus and surrounding structures and may even metastasize to

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the lungs, but tumors are not formed or, if so, they regress. The choriocarcinoma, however, invades, metastasizes, and destroys the host (*5*).

Some believe that a benign colloid goiter (tumor of the thyroid gland) may metastasize to the lungs of man and dogs (*5*). According to my own experience obtained between 1918 and 1925, when all the adult dogs in Chicago were goiterous, I found evidence of local invasiveness in some 10 dogs in which thyroid metastases were formed in the lungs. I was unable, however, to produce lung tumors by introducing small pieces or a "cell" suspension of a thyroid which appeared to be "carcinomatous" into the external jugular vein. This may have been due to the heterologous nature of the tissue used or to other factors. Dr. Huggins, of the University of Chicago, has informed me that he has been unsuccessful when he similarly used hyperplastic prostatic tissue in the dog.

Between 1918 and 1925 I autopsied approximately 2,000 adult dogs in Chicago among which the incidence of goiter was 98 per cent and of "cancer" of the thyroid with gross pulmonary metastases, 1.6 per cent. Goiters and cancer of the thyroid completely disappeared from Chicago dogs after 1925, or one or two years after iodized salt became a general grocery store commodity.

It is difficult, for these and other reasons, to avoid the view that, fundamentally, benign and malignant tumors are manifestations of the same neoplastic principle, the benign tumor or cell representing an arrested or inhibited stage of a potentially malignant process.

Does the cancer cell represent a transformation of a normal cell or a cell abnormal from embryonic life?

All the evidence with which I am familiar may be interpreted as indicating that the cells transformed into malignant cells may arise either from embryonal residues or from normal cells which are more susceptible than other normal cells in the same organ. Even the apparent transformation of fibroblasts into sarcoma cells in tissue culture by treatment with methylcholanthrene, as observed by Earle (*21*), is not sufficiently free from a possible experimental error to invalidate the theory of embryonal residues being involved.

But it is really immaterial, except from a taxonomical point of view, whether a normal cell or an "embryonical residue" is changed. This is true because the growth of fetal tissues and the placenta throughout their normal course is regulated, regardless of the fact that they have a metabolic pattern like malignant tissue. The important biological question is:

What is the nature of the process induced either into the normal cells or, if one prefers, the "embryonal residue" when they become cancerous or truly malignant?

The nature of "the autonomous" or "the malignant process" still appears to be the most fundamental question pertaining to the biology of cancer. It would appear that the rational approach to the secret of the cure of cancer is to ascertain either the factors which are responsible for causing unregulated, unlimited, invasive, metastatic, and destructive growth or those which are responsible for limiting and regulating normal growth.

The autonomous nature of cancer. A tumor is sometimes defined as "an autonomous new growth of tissue" (Ewing). Autonomous implies growth unregulated and independent of the host except for nourishment. Malignant implies destructiveness due to invasiveness and metastasis.

If a malignant growth is entirely autonomous except for nourishment, nothing manufactured in the body of the host except food of some type could influence it. This is not true of some cases of cancer of the prostate with metastasis to the bone in man, since Huggins and his colleagues and others (*10*) have observed the disappearance of metastases in bone and the primary tumor after castration or the administration of large doses of stilbesterol to the patient. The cells of tumors of the prostate and breast which are markedly benefited by modifying the sex hormone supply may not be sufficiently transformed to be entirely autonomous. Of course, it may be that in the case of the prostate, one is dealing with a very special case, since its embryonal development is specifically stimulated or inhibited by male and female sex hormones, respectively. In this connection it would be of interest to know what effect testosterone might have on chorioadenoma (v.s.) and choriocarcinoma (v.s.). It would also be significant to know the effect of the growth-promoting activities of the thyroid gland (*19*) and the anterior lobe of the pituitary gland on the growth of cancer. Would the so-called "anti-hormone" of the thyrotropic hormone produced by the hypophysis affect a carcinomatous thyroid?

The autonomous nature of a malignant tumor should not be viewed too rigidly. A rigid adherence to this hypothesis is probably contrary to the facts, and its pessimistic implications tend to retard discovery of knowledge regarding the nature and cure of cancer. In fact, when one considers all the factors inside and outside the cell which affect growth and the great care which must be exercised in the tissue culture of malignant cells, it is difficult to accept the view that any tumor is completely autonomous relative to its rate of growth, even though it may be completely autonomous in regard to its invasive and metastatic properties.

The uniformity of the chemistry of malignant tissue. The strongest evidence that the malignant process is identical, in what may be termed fully transformed malignant tissue, has been obtained primarily from naturally occurring and artifically induced transplantable tumors. It shows that a marked similarity exists in the chemical properties (composition, enzyme, and metabolic pattern) of a malignant tissue regardless of the species or the histogenetic source of the tumor tissue (*7*). Malignant tissues as a class appear to be as unique chemically as liver tissue or gastric mucosa. I have been particularly awed by the chemical and metabolic similarity of the tissue of a hepa-

toma (metastasizing tumor of a rat's liver) and a gastric adenocarcinoma (cancer produced artificially in a rat's stomach), two tissues which in normal life appear to have very little in common. I have also been impressed by the fact that very rapidly regenerating hepatic tissue has a normal metabolic pattern, whereas hepatoma tissue has the metabolic pattern of malignant and fetal tissue (*7*). The chemical results, of course, support the old theory that malignant tissue represents a reversion to an embryonic type of cell, the growth and reproduction of which is exquisitely regulated and limited. This apparent uniformity of the chemical pattern of malignant tissue may represent an oversimplification, as has been suggested by biochemists working in this field. Regardless of their remarkable contributions, these biochemists recognize that their chemical techniques are still relatively crude and that our knowledge of the chemistry of the normal as well as the cancer cell is in a pioneer state.

If the chemistry of malignant tissues or the malignant process is identical for all malignant tumors and if it is significantly different from normal tissue, one therapy should be applicable to all malignant tumors. The alternate assumption is that the various cancers represent separate malignant processes, or different stages of the malignant process, and a therapy for each will have to be discovered. Morphologically the organ of origin of a malignancy is recognizable in approximately 90 per cent of the cases seen clinically in man. This would suggest that there may exist some competition or overlap between the chemical pattern of the original normal cell and the malignant cell. With present methods this possibility cannot be analyzed with certainty because such a tumor may contain a variable number of premalignant and malignant cells. The answer to this question probably awaits the development of histochemical methods which would reveal the difference between the chemistry of a normal adult cell, an irritated adult cell, a precancerous cell, and a malignant cell. There is no evidence which would show that a cell today has the metabolic pattern of a normal cell and, at the next division, that of a malignant cell. There are geneticists (*25*) who believe that such a somatic mutation may occur and point out that it may explain the alleged "irrevocable character of the malignant change." If such does occur, the fundamental chemical nature of the malignant process could still be the same and respond to a uniform therapy.

Although the malignant process may be essentially the same in all malignant tissues, it may be conditioned or controlled by several factors which vary with the etiology and the tissue from which the tumor arises. If the therapeutic evidence we now have has any bearing on the nature of the malignant process and the factors which condition it, each type of tumor may demand a separate therapy. For example, hormones are used successfully in the treatment of cancer of the prostate and breast; the X-ray sensitivity of various tumors varies widely; and, a definite difference exists in the ease with which toxic substances cause hemorrhage in an experimentally induced sarcoma and carcinoma.

In my thinking of cancer, I frequently use analogously the animal parasites. The "heart worm," or the adult canine filaria, receives its nourishment from the host; it is autonomous with respect to its own growth and reproduction; it is a unique tissue and has a unique metabolism which, however, is probably different from that of other parasites as well as tumor tissue, because its cells are differentiated. Is our problem in cancer, as in the case of parasites, to find a substance which is toxic or essential for each type of cancer, or is it to find one which will be toxic or essential for all cancers? In view of our ignorance, we shall have to accept both as working hypotheses.

In view of the fact that the change in the chemistry and metabolic pattern of a normal or "irritated" tissue into that of malignant tissue is relatively abrupt and distinct in some known respects (*7*), I firmly believe that ways will be found for systemically destroying malignant cells without destroying the normal cells of the host. This is apparently what the X-rays or gamma rays do in the case of cancer of the skin (*6*). I remember being told as a student that gallstones could never be dissolved without dissolving the tissues of the host. Yet, thanks to skeptics who experiment, we now know that if gallstones are placed in the gall bladder of a dog, they are dissolved quite rapidly; so the problem of the solution of gallstones is to find a way to change the fatty acid-cholesterol ratio in human bile toward that found in dog's bile. Similarly, the chemical data obtained on cancer provide much hope and encouragement for the view that further studies will answer the crucial question of the nature of the malignant process, or at least show the way to the proper systemic therapeusis.

Multiplicity of causative factors in tumor genesis. One of the best examples of the multiplicity of factors concerned in the induction of tumors comes from the intriguing studies of the natural occurrence of mammary cancer in many inbred strains of mice. At least three factors are involved: (1) a genetic constitution, or pattern, or inherited susceptibility; (2) the female sex hormone; and (3) the "virus-like" agent transmitted in the milk of the mice (*3*). For example, estrogen must be given to male mice before they will develop the tumor, and spayed females will not develop the tumor unless given estrogen. Though the inciting agent is present in all of the tissues of the exposed mouse, it predisposes only to mammary tumors. In addition, the age at which the agent is introduced is a factor. Even with the best-known combination of these factors, some 9 months are required for the appearance of the tumor, or the latent period of induction is very long in the life of a mouse. And further, though rabbits and rats form a neutralizing antibody for the milk factor, the mouse does not, and an antimouse tissue serum has no effect on it. Finally, though other factors probably exist, the diet

during the period of tumor development exerts an influence on the incidence of the mammary tumors in mice (*26*).

Many other examples exist showing the complexity of the endogenous and exogenous factors concerned in the genesis of cancer in mice. To render the problem still more complex, the species differences are marked, and the influence of factors which predispose to cancer in one species may retard in another species. For example, though reproduction and nursing unequivocally predispose to cancer of the breast in the strains of female mice studied, it has the opposite effect on women.

Paucity of information on the dietary control of cancer. When one reads the literature on the successful inhibition of tumor induction and growth by dietary control, one becomes acutely aware of the paucity of information in this field in relation to its demonstrated importance. Very little is known regarding the existence of any specific nutritional requirements of any kind of tumor, except the hepatoma in the rat, where diet exerts a very significant effect. In view of the fact that specific dietary factors are required for the maintenance, reproduction, and growth of normal cells and that the metabolic pattern of malignant tissue is quite specific and may be found to be more so, it would seem to be advisable to cultivate this field intensively in man as well as animals.

The natural resistance or immunity of certain tissues. One of the most provocative phenomena in the field of cancer is the natural resistance of certain tissues to the natural development of cancer and the acceptance of metastases. Striated muscle, heart muscle, spleen, kidney, and intestinal mucosa are particularly resistant to the development of malignant tumors. In lower forms this applies also to the mucosa of the glandular portion of the stomach. The natural resistance of these tissues has rendered it very difficult for the geneticist to render them susceptible. Yet, we know that tumors of all these organs do occasionally occur, and particularly so in the stomach and large intestine of man. We have no rational notion for the explanation of this natural resistance even in the presence of high-grade susceptibility in other organs. It is not due to a natural resistance to the transplantation of an homologous tissue because thyroid, bone, and other tissues have been transplanted into the spleen and striated muscle.

It is possible to render an animal immune to grafts from another animal (heterologous grafts) depending on the natural resistance of the host and the malignancy of the tissue to be transplanted. This is particularly true when a graft has regressed or, after "taking," has been destroyed by X-ray treatment. But up to the present time no one has demonstrated antibodies to cancer tissue in the serum of the host or has been able to demonstrate in a host immunity to a graft of its own cancer (*1*, *17*).

However, immune reactions have been obtained from the serum of a host with a heterologous transplant and have been explained as due to heterologous tissue proteins (*17*). (It would seem that in such a case the proliferative power of the transplant must be such as to annul any injurious effect of the antibodies, if they have an injurious effect.) The failure to obtain evidence of antibodies in the serum of animals with malignant tumors is consonant with the chemical similarity of proteins in malignant tissue and the normal tissue from which it came (*7*). Antigenically, a crystalline enzyme isolated from the Jensen rat sarcoma was the same as that from rat muscle (*16*). On the contrary, it has been reported that a cathepsin containing protein isolated from a hepatoma (rat) is antigenically more similar to one isolated from a Jensen sarcoma (rat) than that isolated from the normal liver (*18*).

It is discouraging to read the literature dealing with the immunology and serological diagnosis of cancer. Ehrlich (*4*), who worked with the problem for 15 years, is said to have become so discouraged that he stated: "Until some fundamental discovery has solved the mystery of life itself, our knowledge of cancer will not advance a single step." Although an attempt such as Ehrlich made to immunize the body against cancer by inducing resistance against transplantable cancers may not be achieved, work using the new methods for isolating protein and the newer knowledge and techniques of immunochemistry should be applied. At the same time the possibility of developing a method for the serodiagnosis of early cancer should not be overlooked, even though it may be grossly empirical.

The need of a simple test for the diagnosis of early internal cancer is urgent. Cancer of the alimentary tract ranks first as a cause of death from cancer. Cancer of the stomach ranks first in men and second in women. Cancer of the stomach is "silent" or produces no symptoms in 25–30 per cent of autopsied persons dying of the disease (*14*). In fact, the evidence indicates that the disease is overlooked in 50 per cent of the cases which are attended at our best general hospitals, for the incidence of gastric cancer, according to mortality statistics, is 16 per cent of all cancers, and the incidence, according to the records of general hospitals is only from 6 to 8 per cent of all cancers. (Any challenge of these data, which I admit may be in error, simply indicates that we need to increase the descriptive science of the disease.) Not only does a large percentage of silent cases exist, but at least 20 per cent of people die of a surgically resectable cancer or without metastases beyond the adjacent lymph nodes (*22*). The surgical mortality from gastric resection has been reduced to such an extent that it is now possible to state that if we had some simple method for the diagnosis of early gastric cancer, the mortality from this disease could be reduced by from 30 to 50 per cent, and perhaps even more.

The effect of cancer on the host. If early cancer cannot be diagnosed by some serological method, some effect of the cancer on the host may be found before metastasis occurs or after it has occurred to the immediately adjacent lymph nodes, as in the case of the phosphatase test for cancer of the prostate. In fact, the success of this test pro-

vides renewed hope that a test or tests for other internal cancers may be found.

The most striking early effect of a cancer on the biochemistry of the host that seems to be established is the reduction of renal and hepatic catalase. The catalase in the erythrocyte is unaffected. This appears to be specific for a malignant tissue, since it is common to malignant tumors and since the phenomenon does not occur in pregnancy or in the presence of embryonal transplants. According to Greenstein and Andervont (*8*), the liver catalase is significantly reduced in four days after transplantation of a sarcoma in the tail of a mouse. Whether the reduction in renal and liver catalase is unique for a malignant process and what causes it is uncertain.

I select this example of the effect of a malignant tumor on its host only to emphasize that such an approach to the diagnosis of cancer is feasible and, if successful, should contribute greatly toward facilitating the case-finding of internal cancer. There are other leads with promise. In fact, it is improbable that a single diagnostic method for all types of cancer will be found. Several methods may have to be used in a case-finding program.

TABLE 1

SHOWING THAT PRIMARY CARCINOMA OF THE LIVER IS EQUALLY DISTRIBUTED BETWEEN WHITES AND NEGROES AT COOK COUNTY HOSPITAL, CHICAGO, WHERE ONE-THIRD OF THE AUTOPSIES ARE ON NEGROES*

	White	Colored	Total	Per cent of total
Cancer with cirrhosis.....	22†	10‡	32	44
Cancer without cirrhosis.....	26§	14§	40	56
Totals.....	48	24	75	

* Data supplied by Dr. Hans Popper.
† All males.
‡ Three females.
§ Males predominate.

We should remember that the matter of diagnosis will still exist after a cure is found and that we now have the cure for many early cancers.

Man is at present an experimental subject for the study of cancer, as various investigators have pointed out. He is inclined to experiment on himself and produce disease that he might otherwise avoid. Hence, reliably collected and analyzed statistics should provide valuable information regarding the cause and prevention of cancer—particularly cancer of the stomach. For example, present statistics indicate that cancer of the stomach occurs twice as frequently in the Dutch as in the British. Is this true? And, if so, what is the cause? It has been ascribed to the greater consumption of irritants in the food and drink by the Dutch. The evidence is equivocal (*12*). The same situation obtains for the Chinese in Java who have a higher incidence of cancer than the native Javanese who have a low incidence (*12*). Statistics from England indicate that the incidence of cancer of the stomach is higher in the lower- than the higher-income group (Stevenson, 1921). Taking another internal cancer, the autopsy incidence of primary cancer of the liver in the South African Bantu is 37.5 per cent (*15*). In the West African Negro the disease represents 18.7 per cent of all deaths from cancer. In European countries cancer of the liver makes up only 1.1 per cent of all cancer deaths. Statistics from the Cook County Hospital, Chicago, show that this marked difference in the incidence of primary cancer of the liver between whites and Negroes can hardly be due to a genetic difference. At autopsy primary cancer of the liver constitutes 1.1 per cent of all cases of cancer as in Europeans, and the incidence is the same in the whites and Negroes (see Table 1). Such observations strongly indicate that extrinsic factors are concerned in the genesis of cancer of the stomach and liver. This should warrant and stimulate a thorough search among foods and drinks for carcinogenic agents. An agent in heated fats and something produced by heating cholesterol have been shown to cause sarcoma occasionally when injected subcutaneously in mice or rats. Nevertheless, it has not been established that the feeding of heated fat, cholesterol, or irradiated cholesterol will cause cancer of the stomach in the experimental animal. However, P. R. Peacock (*23*) observed a cancer of the stomach to develop in one of 6 rats when some croton oil was added to heated (350°C.) cotton-seed oil. The fact that one can demonstrate carcinogenic substance in heated fats (to the point of browning) by subcutaneous injection should render them suspect when taken daily over years. We should recall that in the case of gastric cancer in man we are looking for the cause of a disease which occurs only in approximately 1 out of 750 persons above the age of 40 (*13*). Also, a long latent period can be anticipated because a feeble carcinogen must act over a long period to induce a tumor—perhaps 30 years or more in man. The story of the experimental demonstration of the carcinogenic activity of tar should suffice to illustrate this point. Tar is a feeble carcinogen compared to the benzpyrene which was extracted from it.

I have taken advantage of this occasion to give special mention to the problem of gastric cancer because it heads the list of the organ sites for cancer in man. We know less about its cause and diagnosis than any of the external cancers. Gastric cancer has been neglected by the investigators in the field of cancer probably because it has not been easy to produce by genetic procedures and exogenous carcinogens.

In view of the progress in the basic knowledge of cancer made during the last 20 years and the availability of new chemical and physical tools, and the fact that funds appear to be forthcoming for an attack on all fronts, the possibility of great discoveries being made in the next 10 or 20 years looks very encouraging.

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Recent Changes in Sedimentation in the Gulf of Mexico

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THAT SEDIMENTS IN THE GULF OF Mexico have changed materially in relatively recent time has been established by a recent expedition of the *Atlantis*, the oceanographic research vessel of the Woods Hole Oceanographic Institution. Deposits clearly associated with the Ice Age lie within a foot or two of the surface of the sea floor over a large part of the Gulf.

The *Atlantis* spent the months of February and March 1947 in the northwest part of the Gulf of Mexico, primarily for the purpose of investigating the environmental conditions of deposition of sediments. The expedition was sponsored jointly by the Woods Hole Oceanographic Institution and the Geological Society of America. The latter contributed a grant of $14,500 for this purpose to the authors of this communication, while the Oceanographic Institution supplied the vessel, crew, and scientific personnel for the expedition and made available laboratory facilities and personnel for working up the results.

Despite considerable rough weather, the expedition was remarkably successful. Some 550 short cores of the bottom sediments, ranging in length from 5 to 50 cm., and 100 long cores, ranging in length from 1.5 to 3.3 m., were collected. Twelve lines of samples transverse to the coast across the continental platform from the mouth of the Rio Grande to the mouth of the Atchafalaya River, and 7 lines across the continental slope out to the deepest part of the Gulf, were taken. In addition, about 100 stations were occupied for plankton tows, serial temperature, and samples of water. Several hundred temperature-depth records were made with a bathythermograph along the lines of traverse, and continuous depth records were made with a recording fathometer. The material collected is now being actively worked up at the Woods Hole Oceanographic Institution. The U. S. Bureau of Mines Experimental Station at Pittsburgh, Pennsylvania, through the courtesy of H. M. Cooper, supervising chemist of the Coal Analysis Section, is cooperating in this work by making analyses of the organic content of the sediments.

A preliminary examination of 12 long cores distributed representatively throughout the off-shore waters of the Gulf shows two distinctly different layers of sediment: (1) an upper zone of globigerina ooze, rich in calcium carbonate, 5–50 cm. in thickness, and (2) a lower zone of alternating bands of clay and extremely well-sorted, fine-grained silt, relatively poor in calcium carbonate. Although in a few places the two zones are separated by a layer of red clay or red mud of intermediate calcium carbonate content, in most cores the transition from alternating clay and silt to globigerina ooze is fairly abrupt. Cores from the area off the Rio Grande contain a few centimeters of foraminiferal ooze at the top, below which is fine silt extending to the bottom of the core. No alternating bands of clay and well-sorted silt have been noted in this area.

The lower zone of banded clay found throughout most of the Gulf consists of alternating layers of clay, 1 mm. to 30 cm. thick, and of silt, 0.2 mm. to 5 cm. in thickness. Most of the clay bands are 1–2 cm. thick; most of the silt bands, less than 1 mm. The silt is so well sorted that under a high-power binocular microscope it has the appearance of ordinary beach sand. Its average (median) diameter is estimated to range between 10 and 20 μ. Such good sorting in such a fine silt is most unusual.

Well-defined cross-bedding was noted in two cores: one, at a depth of 170 cm. beneath the sea floor in a sample taken from a sea mount near the edge of the con-

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