It is often impossible to arrive at a single radiologic diagnosis of bone tumors. "Look-alikes" abound, and it may be difficult to be more specific about a given lesion than to list the differential possibilities, with the most likely first. Nevertheless, the radiologic appearance of a bone tumor is an indispensable piece of evidence and sometimes provides a more accurate guide to its nature than the pathologic specimen (especially when representative samples are not obtained from all parts of the tumor).¹

Bearing in mind these considerations, it is essential to first determine whether a tumor is benign or malignant. Clarity on this point is of great help to proper clinical management. (Table 1.)

In evaluating potential malignancy of a tumor, the zone of transition—the line of demarcation between tumor substance and adjacent normal bone—should be inspected first. If the zone of transition is narrow, with a sharp and distinct border between tumor and surrounding normal bone, the lesion can be classified as slowly growing and probably benign.

On the other hand, if the zone of transition is wide and the tumor appears to infiltrate surrounding normal bone without clearly defined margins, it is usually rapidly growing and potentially malignant. Tumor margins should be closely inspected on all available projections, as a small segment of infiltrative tumor may be missed in an apparently benign lesion.²

Benign bone lesions are often surrounded with a thick rind of cortical bone. This indicates a "lazy" or slow-growing lesion.³ The bony shell, or marginal sclerosis, is produced by the host bone in response to the tumor, and its thickness is directly proportional to the chronicity of the tumor and inversely proportional to the tumor’s speed of growth.

Similarly, trabeculation often results from irregular ridging of the bony shell. Coarser trabeculation points to a slowly growing tumor; finer trabeculation, or none at all, indicates a more rapidly expansile lesion.

Pathologic fracture through a bone tumor may occur in both benign and malignant lesions, but extensive cortical breakthrough by the tumor suggests malignancy, especially when tumor extension into the adjacent soft tissues is demonstrated on the radiograph.

Although the presence of periosteal reaction does not automatically indicate

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¹ Dr. Osborne is Associate in Radiology, Duke University Medical Center, Durham, North Carolina.
cancer, it is an index of the rapidity of tumor growth. A lamellated “onionskin” or speculated “sunburst” periosteal appearance carries a high correlation with cancer.

Codman’s triangles, small triangular densities of periosteal reaction occurring where the periosteum has been elevated from the bone by an expanding mass, may be encountered in both benign and malignant conditions, and are not diagnostic of cancer.²

Tumor size should be taken into consideration as well; benign bone tumors may sometimes achieve considerable size, but in general the larger the lesion, the more likely it is malignant.

Lodwick introduced another useful evaluative criterion by relating the overall roentgen appearance of the lesion to its speed of growth.⁴ He distinguished between geographic, moth-eaten and permeative appearances of a bone tumor. A geographic appearance is one of coherent alteration in normal bone texture with well-defined margins, indicating relatively slow growth. Giant cell tumors are sometimes examples of this. More rapid growth may result in a moth-eaten appearance, in which the tumor produces multiple foci of destruction with indistinct edges, indicating tumor escape from its confines within the bone. This is frequently encountered in reticulum cell sarcoma. Finally, extremely rapid spread may produce a permeative appearance, in which the bone shaft is riddled with innumerable small defects for a considerable distance beyond the central focus of tumor destruction. This is sometimes seen in Ewing’s tumor.

Having made a preliminary assessment of the nature of a bone tumor, identifying characteristics help establish the diagnosis. (Table 2.) The patient’s age is of great importance, as many bone tumors demonstrate sharp peaks of incidence in certain decades of life and are almost unknown in others. Statistically, reticulum cell sarcoma is infrequent before the age of 20 years, whereas Ewing’s tumor is uncommon after this age. Osteosarcoma shows a peak incidence in the second decade and declines rapidly thereafter.¹ Cases arising in the later years may represent sarcomatous degeneration following Paget’s disease or previous bone irradiation. Giant cell tumors are rarely encountered before the epiphyses have closed. In a patient over 50 years of age, the most common cause of a bone tumor is carcinomatous metastasis. In an infant under six months of age, the same picture statistically represents a neuroblastoma.²
The site of origin of a bone tumor provides another useful clue. In the epiphysis of a long bone, a well-margnated sclerotic tumor is likely to be a chondroblastoma; in a similar location, but after the epiphysis has closed, a giant cell tumor is most likely. The metaphyseal zone is a common site of origin for primary sarcomas of bone arising from any of the mesenchymal tissues involved in bone formation: fibrous tissue, cartilage or bone itself. Certain benign lesions, such as bone cysts and fibrous cortical defects, originate near the epiphyseal plate, but "migrate" toward the diaphysis with growth and elongation of the bone. Solitary bone cysts, chondromas and fibrous dysplasia all appear centrally within the medullary canal of a long bone, whereas chondromyxoid fibromas and giant cell tumors are characteristically eccentric, involving one cortex and extending inward toward the marrow cavity. Round cell tumors (such as multiple myeloma, Ewing's tumor and reticulum cell sarcoma) tend to originate at the metaphyseal-diaphyseal junction, although tumor spread may be so extensive at the time of diagnosis that the exact zone of origin is difficult to assess. In some cases, the involved part of the body may suggest a diagnosis: a destructive midline lesion of the clivus or sacrum may be a chor-

| Table 1. Clues in the Preliminary Assessment of Bone Tumors |
|-------------------------------------------------------------|
| **Radiologic Finding** | **Benign Bone Tumor** | **Malignant Bone Tumor** |
| Zone of transition | Narrow zone of transition, with sharp and distinct border between tumor and normal bone. | Wide zone of transition; tumor appears to infiltrate surrounding normal bone, without clearly defined margins. |
| Marginal sclerosis | Lesion surrounded with a thick rind of cortical bone. | Lesion surrounded with a thin rind of bony shell. |
| Trabeculation | Coarse trabeculation. | Fine trabeculation, or none at all. |
| Cortical breakthrough | Pathologic fracture may occur, but is not extensive. | Cortical breakthrough is extensive, possibly with tumor extension into adjacent soft tissue. |
| Periosteal reaction | Codman's triangles may be present in both benign and malignant lesions. Periosteal reaction is single layered. | A lamellated "onion-skin" or speculated "sunburst" appearance. Periosteal reaction is multi-layered. |
| Tumor size | Generally small. | Generally large. |
| Overall roentgen appearance | Geographic appearance, i.e., coherent alteration in normal bone texture with well-defined margins. | Motheaten appearance, i.e., multiple foci of destruction with indistinct edges, or. Permeative appearance, i.e., bone shaft is riddled with small defects for a considerable distance beyond tumor focus. |
doma; an irregular, mixed lytic and sclerotic lesion involving the middle third of the anterior tibial cortex may prove to be an adamantinoma.\textsuperscript{2}

The \textit{tumor substance}, or matrix, often indicates tumor origin or constituents. Increased bony density or sclerosis is commonly seen in many tumors both benign and malignant, but extensive, ill-defined increased density around a bone tumor may indicate osteogenic sarcoma, the only bone tumor in which osteoid is directly produced by the tumor cells. The tumor is then said to have an osteoid matrix. Similarly, multiple small, punctate, "snowflake" calcifications, often arranged in small arclike or ringlike configurations, characterize cartilaginous tumors. These radiodensities result from small foci of calcification and ossification of the chondroid matrix. The fibroid matrix of fibromas and fibrosarcomas does not calcify, and appears uniformly lucent on the radiograph. In all bone tumors, apart from those with osteoid or chondroid matrix in which increased density or sclerosis is seen, the sclerosis results from attempted reparation by the normal bone surrounding the tumor, and is not produced by the tumor itself.

\textit{Tumor involvement} of one or many bones provides another key to diagnosis. Cancers commonly involve many bones by metastatic spread; less fre-

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Clues} & \textbf{Type of Tumor} & \textbf{Identifying Characteristics} \\
\hline
\textbf{Patient's Age} & Reticulum cell sarcoma: Infrequent before age 20 years. & Ewing's tumor: Uncommon after age 20 years. \\
& Osteogenic sarcoma: Peak incidence in second decade. & Grant cell tumor: Rarely encountered before epiphysis has closed. \\
& Metastatic cancer: Most common bone cancer after age 50 years. & \\
\hline
\textbf{Site of Origin} & Chondroblastoma: The epiphysis of a long bone. & \\
& Grant cell tumor: Similar location to above, but after epiphysis has closed. & \\
& Primary sarcomas of bone: The metaphyseal zone. & \\
& Bone cysts and fibrous cortical defects: Near epiphyseal plate, but migrates toward diaphyses. & \\
& Aneurysmal bone cysts, chondromas and fibrous dysplasia: Centrally within medullary canal of long bone. & \\
& Round cell tumors: Junction of Metaphysis and diaphysis. & \\
\hline
\textbf{Tumor Substance} & Osteogenic sarcoma: Osteoid matrix with extensive ill-defined density around bone tumor. & \\
& Cartilaginous tumors: Chondroid matrix with multiple small "snowflake" calcifications, often arranged in arclike configurations. & \\
& Fibroma, fibrosarcoma: Fibroid matrix, without calcification; appears uniformly lucent on X-ray. & \\
\hline
\end{tabular}
\caption{Clues in the Differential Diagnoses of Bone Tumors}
\end{table}
Osteochondroma

The most common bone tumor, osteochondroma, or osteocartilaginous exostosis, represents a developmental anomaly in which a portion of the growth plate near the end of the bone is diverted, but continues to produce ectopic bone on the surface of the bone shaft. (Fig. 1.) These exostoses characteristically point away from the bone end of origin, and are covered by a cartilaginous cap, the aberrant growth plate fragment, which adds bone to the lesion. Growth usually continues until epiphyseal closure elsewhere in the body. The trabecular architecture of the supporting bone shaft is influenced by the osteochondroma, and appears to flow toward it, distinguishing it from other calcified masses adherent to the bone surface, which do not disturb the trabecular architecture. (Fig. 2.) Osteochondromas may be multiple, a condition described as multiple hereditary exostoses. Multifocal origin of primary bone cancers may be encountered. Many malignant and most benign bone tumors are monostotic, involving one bone only, and the finding of polyostotic involvement in apparently benign lesions raises the possibility of a non-neoplastic disease.

Benign Bone Tumors

Osteoma

This is a benign tumor arising in areas of membranous bone formation in the skull, most often the calvarial tables, frontal or ethmoid sinuses. Radiologically, osteomas are usually small, round and dense, and may be associated with Gardner’s syndrome, especially if more than one osteoma is present. When osteomas involve the inner table of the calvarium, differentiation from meningioma may be impossible without special studies.

Fig. 1. Osteochondroma. The lesion is extending laterally from the head of the radius. Osteochondroma

Fig. 2. Osteochondroma. The trabecular structure of the host bone "flows into" the osteochondroma.
ostosis or diaphyseal aclasis, when abnormal modeling of the bone ends occurs in multiple sites. (Fig. 3.) Malignant degeneration of an osteochondroma occurs in less than one percent of solitary lesions, but may result in as many as 20 percent of the multiple form. As a general rule, the thicker the cartilaginous cap (with its characteristic punctate calcification) in a single exostosis, the greater the risk of malignant transformation, usually into a chondrosarcoma. Further growth or symptoms after skeletal maturity should be viewed with concern.

**Enchondroma (Chondroma)**

Enchondromas may develop within any bone arising embryologically from enchondral ossification and may be multiple. They are most common in the fingers and toes, but may occur proximal to the trunk. (Fig. 4.) The closer a chondroma lies to the trunk, the more likely it is to become malignant. Most enchondromas are asymptomatic. When they produce pain or increase in size in the adult, malignant change must be anticipated. Multiple enchondromas resulting in severe skeletal deformity, with a tendency to unilaterality, are known as Ollier’s disease, a dysplasia of bone rather than a true neoplasia. Nevertheless, there is a greatly increased risk of malignant degeneration with multiple chondromas, eventually reaching 50 percent in some series.

The roentgen appearance of the enchondroma is similar to a cartilaginous tumor, i.e., stippled, punctate or ‘snowflake’ calcification in the matrix. It has scalloped or lobulated but well-defined edges and a narrow zone of transition, usually located centrally within a long bone shaft. The same lesion situated eccentrically beneath the periost-
but they more often have a lucent or only faintly hazy center. These tumors may extend into the metaphysis of the bone, especially after fusion of the epiphysis, and can cause bulging and thinning of the cortex as may all benign bone tumors. The cortex may be thinned to the point of becoming invisible on X-ray but it will not be penetrated by tumor unless pathologic fracture has occurred.

Osteoid Osteoma

Considerable debate exists as to whether this lesion represents an obscure bone infection or an actual neoplasm. Whatever its cause, the tumor’s characteristic clinical picture is one of gradually progressive pain, worse at night and often relieved by salicylates. Children and young adults are commonly affected, with a distinct predilection for the male sex. Radiographic diagnosis depends on demonstration of a

Benign Chondroblastoma (Codman’s Tumor)

The most characteristic finding in benign chondroblastoma is its eccentric location in the epiphyseal ossification center of a growing long bone, often the proximal humerus. (Fig. 5.) As a result, they are encountered predominantly between the ages of 10 and 20 years, usually before the epiphyses close. A male sex predilection has been reported. As with all benign bone tumors (with the exception of cysts and osteoid osteomas), malignant degeneration may occur, but it is distinctly rare. The tumor appears radiologically benign, with a sclerotic margin. Chondroblastomas may contain the typical snowflake calcifications of cartilaginous tumors,
nidus, a small, round lucency less than 5 mm in diameter, surrounded by reactive bony sclerosis. (Fig. 6.) The nidus may look clear or contain central calcium densities. The degree of reactive sclerosis depends on its location. Those occurring within the cortex excite the densest cortical thickening; those within cancellous endosteal bone result in the least sclerosis. Curettement of the nidus results in complete cure. Malignant transformation is unknown.

Benign Osteoblastoma

Benign osteoblastoma, also called giant osteoid osteoma, represents a true neoplasm and occasional malignant change has been documented. Osteoblastomas are larger than osteoid osteomas, and less likely to be surrounded with dense, reactive bone. The tumor substance may be lucent, or show a hazy, “ground glass” consistency often noted in fibrous dysplasia. Benign osteoblastomas occur most commonly in the second and third decades, and have a male sex predilection. They show an affinity for the vertebral arches and spinous processes, and over half of all lesions occur in the posterior spine, sometimes resulting in cord compression. When an osteoblastoma involves a long bone, it appears in the metaphysis or the diaphysis of the shaft, and may markedly bulge the cortex, resembling an aneurysmal bone cyst.

Giant Cell Tumor

The giant cell tumor (osteoclastoma) contains large numbers of multinucleated giant cells or osteoclasts on microscopic examination. This feature is common to many benign bone lesions, but the giant cell tumor is nonetheless distinctive radiologically and pathologically. It is one of the few bone tumors showing a predilection for the fe-
transformation. Metastases have been reported with histologically "benign" tumors. (Fig. 9.) There is no way to correlate the radiologic appearance of a giant cell tumor with its clinical behavior. Grading for malignant potential depends entirely on the microscopic appearance of the tumor, and even this can be misleading if representative samples are not obtained from all parts of the tumor.

Fibroxanthoma (Non-Ossifying Fibroma, Non-Osteogenic Fibroma, Fibrous Cortical Defect)

This bone lesion is generally thought to represent a focus of faulty ossification rather than a true neoplasm. The distinction is not always clear, however, as the larger tumors behave very much like benign lesions. Only occasionally do they produce symptoms; fibroxanthomas are usually discovered by chance in an ex-

Fig. 9. Giant cell tumor. This rapidly growing lesion has destroyed most of the metacarpal

male sex, and is most commonly encountered in the third decade of life, appearing very rarely before the epiphyses have closed. Its location is also characteristic, as it involves the epiphysis or bone end eccentrically and extends to touch the subchondral bone plate. The giant cell tumor is frequently a classic example of Lodwick’s geographic lesion, with a narrow zone of transition but no marginal sclerosis. The tumor matrix appears lucent. (Fig. 7.) More slowly growing lesions may demonstrate marginal sclerosis and a trabeculated, "basketweave" appearance resulting from ridging of contours in the tumor surface. (Fig. 8.) The faster growing the lesion, the finer are these trabeculations, to the point of complete disappearance.

All giant cell tumors have a malignant potential, either for change into a more malignant variant or for sarcomatous

Fig. 10. Fibroxanthoma. Note the marginal sclerosis and eccentric location in the metaphysis.
tremity being radiographed for an unrelated complaint. The fibrous cortical defect is a small, eccentric lucency in the cortex of a long bone metaphysis, located a variable distance from the epi-
physeal line. (Figs. 10 and 11.) With bone growth, the defects ‘‘migrate’’ toward the diaphysis and become more elliptical in contour, parallel with the long axis of the bone. Fibrous cortical defects may involve multiple sites in a bone, or may be polyostotic. They are almost never seen in patients over 25.

Hemangiomas

The calvarium and vertebral bodies are the most common sites for these generally solitary lesions. Hemangiomas show a female predominance, and are most often noted in the middle or later years of life. The typical vertebral appearance is one of exaggerated trabeculation of the vertebral body, resulting from attrition of some of the trabeculae by the expanding hemangioma, and thickening of the remaining ones by attempted healing. Although many vertebral hemangiomas represent chance findings, they may produce pain or collapse of the vertebral body, or in some cases result in cord compression.

Hemangiomas of the calvarium expand the tables of the skull locally, but are very slow-growing and show little change with time. Dense trabeculation is noted within the lesion, which may be of a fine ‘‘honeycomb’’ or ‘‘bubbly’’ appearance, or may show radial striations outward in a ‘‘sunburst’’ effect. (Fig. 12.) (This should be distinguished from the periosteal ‘‘sunburst’’ of a highly malignant bone lesion encountered elsewhere.) Hemangiomas are generally benign lesions, but rarely exhibit polyostotic or soft tissue involvement, or result in diffuse osteolysis.
Malignant Bone Tumors

Myeloma

The most common primary bone cancer, myeloma consists of proliferating plasma cells, and arises most often in bones containing red marrow in the adult. Myeloma shows a predilection for males, and is seldom encountered before the fourth decade of life. The tumor is often associated with fever, bone pain, anemia, an increased sedimentation rate, peripheral neuropathy, hypercalcemia, serum globulin abnormalities, and renal dysfunction with excretion of Bence-Jones protein, all of which may be absent at the time of initial diagnosis. (Fig. 13.) Myeloma may present radiographically in one of four different ways:

1. Multiple myeloma, the most common variety, exhibits numerous "punched-out" lytic lesions throughout the skeleton, with well-defined edges but no marginal sclerosis. (Fig. 14.) Rib involvement with "ballooning" is characteristic; periosteal reaction is rare. The overall roentgen appearance may closely resemble that of extensively disseminated metastatic carcinoma, but myeloma tends to spare the vertebral pedicles and involve the mandible, whereas metastatic carcinoma does the reverse. Osteoblastic forms occur in three percent of cases.\(^5\)

2. Myelomatosis is seen with extensive infiltration of the bone marrow with myeloma cells, resulting in an X-ray appearance indistinguishable from senile or postmenopausal osteoporosis. (Fig. 15.) Follow-up films show progression with multifocal vertebral collapse and pathologic fractures.

3. Solitary myeloma is a slowly expanding lytic lesion, arising in the same sites as other forms of myeloma,
In general, patients with reticulum cell sarcoma appear in better health and have fewer systemic complaints at the time of diagnosis than patients with other primary bone cancers. Reticulum cell sarcoma is often encountered in the third and fourth decades of life, involving a younger age group than is sometimes supposed.

Radiologically, reticulum cell sarcoma presents the classic example of Lodwick's "motheaten" appearance. (Fig. 16.) It first appears in the medullary cavity of a long bone as one or more foci of indistinct erosion, usually in the diaphyseal region. The lesion shows indistinct margins and a wide zone of transition. It grows in size, coalesces, and permeates along the marrow cavity. At the same time, it penetrates the cortex to produce periosteal reaction and soft tissue masses adjacent to the bone. Patho-

Fig. 15. Myelomatosis. Extensive skeletal involvement by myeloma.

but which precedes multiple myeloma by a variable period of time. The disseminated form usually supervenes in one to two years; however, patients with solitary myeloma have been followed as long as 18 years without evidence of further involvement.6 Solitary myelomas often manifest a "bubbly" appearance due to surrounding thick trabeculations and may, therefore, resemble other slowly growing cancers, as well as benign conditions such as the brown tumor of hyperparathyroidism, histiocytosis X or hemangiomas.

(4) Extramedullary myeloma occurs most often in the soft tissues of the nasopharynx or oral cavity, and carries a better prognosis than other forms.

Reticulum Cell Sarcoma

This tumor may be grouped with lymphoma and Hodgkin's disease, which produce radiographically similar lesions.
logic fracture is more frequent than with any other bone tumor. Reactive sclerosis may result in increased density or the lesion may remain purely lytic.

Reticulum cell sarcoma may be difficult to distinguish from Ewing’s tumor both radiologically and pathologically, but tends to affect an older age group and carries a considerably better prognosis (up to 50 percent five-year survival, the best accorded any primary tumor of bone). Purely lytic forms of osteogenic sarcoma may also closely resemble reticulum cell sarcoma, but the latter does not produce calcification or ossification in its associated soft tissue masses, and involves somewhat older patients.

Ewing’s Tumor

Ewing’s tumor carries the gravest prognosis of all primary bone tumors. A tumor of children and young adults, it is infrequently encountered in patients after age 25 years. Pathologically, Ewing’s tumor is grouped with the round cell tumors and may be difficult to distinguish from them on microscopic examination. It presents as a painful, swollen, warm, erythematous mass, usually with fever, malaise, leukocytosis and an increased sedimentation rate.

Its appearance on radiography is consistent with either neoplasm or inflammation; biopsy may be required. The roentgen image of an expansile lesion in the shaft of a long bone with lamellated, “onion-peel” periosteal reaction and Codman’s triangles, which have been described as typical of Ewing’s tumor, is actually encountered in a minority of patients. Ewing’s tumor may appear as diffuse, permeative lysis of bone, or as a lytic geographic defect with minimal periosteal reaction. (Fig. 17.) In other cases it will aggregate beneath the
sidered in the differential diagnosis. Histiocytosis X or eosinophilic granuloma may simulate Ewing’s tumor on X-ray.

Chondrosarcoma

Arising from pre-existing enchondromas, osteochondromas or de novo in any bone embryologically preformed in cartilage, chondrosarcomas are about half as common as osteogenic sarcomas. They are more often encountered in the middle or later years of life, and as is true of enchondromas, chondrosarcomas are more likely to develop in centrally located cartilage tumors; enchondromas proximal to the hands and feet should be regarded with suspicion. Similarly, any increase in tumor size in an adult, or the appearance of tumor-related symptoms is alarming.

Chondrosarcomas may be central, within the shaft of a bone, peripheral, periosteum to produce a saucer-like defect in the cortex, and may be accompanied by dense spiculated or laminated periosteal reaction. (Fig. 18.) It metastasizes rapidly to the lungs and other bones.

As has been noted with reticulum cell sarcoma, Ewing’s tumor may also closely resemble the lytic form of osteogenic sarcoma on the radiograph; the finding of ossification in an adjacent soft tissue tumor mass indicates the latter diagnosis. Unlike Ewing’s tumor, reticulum cell sarcoma manifests a larger associated soft tissue mass at the time of initial diagnosis. Its lytic defects also tend to be larger and less multifocal than those of Ewing’s tumor, and it involves a slightly older age group. Patients with reticulum cell sarcoma will initially appear much less ill than those with Ewing’s tumor. In patients under five years old, neuroblastoma must be con-

Fig. 19. Chondrosarcoma. Small calcified arcs, rings, and “snowflake” appearance suggest cartilage tumor.

Fig. 20. Osteogenic sarcoma. The tumor has produced increased density of the distal femur with multilayered, malignant periosteal reaction.
arising from the periosteum, or in a pre-existing osteochondroma. Central chondrosarcomas expand the cortex and often result in considerable marginal sclerosis or endosteal bone "buttressing" within the shaft of a long bone. Stippled or "snowflake" cartilage calcification within the tumor matrix may indicate a cartilaginous tumor, but is sometimes absent. (Fig. 19.) The zone of transition is likewise variable: when it appears narrow, with no cartilage calcification, the roentgen appearance may be that of an entirely benign lesion. In cartilage tumors, therefore, the usual roentgen criteria for benignity are unreliable. More centrally situated tumors are especially prone to cancer.

Peripheral chondrosarcomas arising in exostoses may show greater thickening, loss of definition and increased calcification of the cap. These observations are especially valid if previous films are available to document these changes over a period of time or if growth in the cartilage cap has occurred after the onset of skeletal maturity.

Calcified cartilage often gives an appearance of multiple, tiny rings or curves, and the tumor margins are sometimes scalloped or indented by the loculated tumor cartilage. When present, these features suggest cartilaginous tumor, but centrally located chondrosarcomas sometimes produce only irregular endosteal bone proliferation without any central calcification, and may be mistaken for chronic osteomyelitis. More aggressive lesions, without cartilage calcification, may be radiologically indistinguishable from fibrosarcoma or the lytic variety of osteogenic sarcoma.

Osteogenic Sarcoma

An osteogenic sarcoma may be defined as a sarcomatous tumor in which
The most common form is the central osteogenic sarcoma, which may be either an osteoblastic (increased bone density) or an osteolytic (decreased density) lesion, but most often is a mixture of both. The lesion usually involves the metaphysis of a long bone, most often about the knee, and at the time of diagnosis has usually extended through the width of the shaft. Areas of altered bone density exhibit a wide zone of transition with normal bone, and intermingle in the tumor substance in an indistinct manner. Where the tumor encounters cortex it rapidly penetrates the bone, resulting in florid periosteal reaction and prominent soft tissue masses extending out from the tumor site. Periosteal reaction is characteristically interrupted and multilayered, often exhibiting either a radial “sunburst” or a laminated “onion-peel” appearance. (Fig. 20.) Codman’s triangles may be noted in the periosteum.

osteoid is directly produced by the tumor cells. Chondroid, fibroid and myxoid elements are often present to a variable extent: the presence of tumor osteoid establishes the diagnosis, even if only a small quantity is present.

Osteogenic sarcoma may occur at any age, but the incidence is markedly increased in the first and second decades and declines rapidly thereafter. A small peak in incidence in the sixth and seventh decades due to osteosarcomatous degeneration of Paget’s disease of bone is disputed. Osteogenic sarcoma shows a predilection for the male sex, with the exception of parosteal sarcoma, which shows a more equal sex distribution. The tumor presents clinically with pain and swelling in the affected part, and laboratory determinations show an elevated serum alkaline phosphatase level.

Several types of osteogenic sarcoma are distinguishable on the radiograph.
at the junction of the tumor with normal bone. (Fig. 21.) These also occur in benign lesions, and are not in themselves diagnostic of cancer. The finding of fluffy calcification of tumor osteoid in an adjacent soft tissue mass is strongly suggestive of osteogenic sarcoma as is dense, fluffy new bone within the central lesion. Purely lytic forms of osteogenic sarcoma may be impossible to diagnose on roentgen appearance alone, for fibrosarcomas and malignant giant cell tumors may appear identical. (Fig. 22.)

The prognosis in osteogenic sarcoma is grave. The tumor disseminates early and widely through the bloodstream, and although the chest film may be clear at the time of diagnosis, subsequent pulmonary metastases often rapidly appear. These too may be calcified. Tumor metastases to bone are also frequent. Rarely, a multicentric primary form, osteosarcomatosis, may be encountered in children between the ages of six and nine years, exhibiting symmetrical, sclerotic osteogenic sarcomas of the extremities in the same stage of development. In addition to arising in bones previously affected with Paget’s disease, osteogenic sarcoma may result from previous irradiation of bone, and rarely in soft tissues quite apart from bone.

Parosteal sarcoma is a comparatively slow-growing variant of osteogenic sarcoma which originates on the surface of the bone from the periosteum, growing outward and characteristically encircling the bone with a prominent mass of calcifying osteoid and cartilage. Parosteal sarcomas are at first separated from their cortex of origin by a thin black line, representing the width of the periosteum on the radiograph. This black line is interrupted at one point by a bony stalk unifying cortex and tumor; this stalk enlarges with time, securing a progressively broader base, until the entire tumor mass has fused homogeneously with the cortex. Eventually the tumor mass may penetrate the cortex to gain the medullary cavity, at which time the prognosis becomes the same as that of central osteogenic sarcoma.

Parosteal sarcoma should be differentiated from osteochondroma, in which the trabecular structure of the underlying shaft appears to “flow into” the stalk. Myositis ossificans involving soft tissues near the bone may appear on the roentgen film as vague densities aligned with soft tissue planes, which later mature to form islands of bone with well-defined cortical margins, unlike the fluffy, indistinct borders of parosteal sarcoma.

**Fibrosarcoma**

This is a malignant tumor of fibrous tissue, which arises within the medullary cavity of a bone, from its periosteum, or in the adjacent soft tissues. It occurs at all ages, more frequently involving patients in middle and later life. (Fig. 23.) No sex predilection has been noted. Fibrosarcoma has a somewhat better prognosis than osteogenic sarcoma, but similar management is required. It may also spread to the lungs via the bloodstream, as well as via lymph channels, being one of the few bone tumors to behave this way.

The roentgen appearance of fibrosarcoma is that of a malignant bone lesion without calcification of the matrix. It may involve long or flat bones; the pelvis is a frequent site in older patients. In the long bones, fibrosarcoma tends to arise at the junction of the metaphysis with the diaphysis.

It may be impossible to radiologically differentiate fibrosarcoma from the lytic form of osteogenic sarcoma, malignant giant cell tumor or chondrosarcoma without matrix calcification. It is helpful to remember that osteogenic sarcoma is less common in older patients, and that giant cell tumor involves the bone end, abutting on the articular plate. Occasionally a small sequestrum of dead bone will appear. Fibrosarcoma may ex-
expand the cortex of a bone to simulate an aneurysmal bone cyst. The latter has a greater tendency to eccentricity in location, however, while fibrosarcoma origi-
nating within a bone is often more centrally located. Aneurysmal bone cysts, if followed by repeat radiographs, often increase dramatically in size; fibrosar-
coma is a more slowly progressing lesion. An associated prominent soft tissue mass, which shows no calcification within, is often present.

Metastatic Cancer

Metastasis to the skeleton from a primary cancer elsewhere in the body is the most common form of malignant bone tumor. Metastatic disease should be the first consideration when the radiologic appearance of bone cancer is encountered in a patient over 50 years old. The tumors most prone to metastasize to the skeleton are those arising in the breast, lung, prostate, thyroid and kidney. Metastatic involvement of the skeleton occurs chiefly in the red marrow areas of the adult (skull, spine, ribs, pelvis, proximal humeri and femora), but involvement of limb bones distal to these areas is not infrequent. Metastatic de-
posits may appear osteolytic, osteoblas-
tic or a mixture of both on the radiograph. Lesions may be single or multiple. The marginal sclerosis of benign lesions is absent; periosteal reaction is sometimes present. Blastic lesions result from osteoblastic reaction of the host bone to the presence of tumor cells, for bone is not deposited by the tumor cells themselves. Metastases from prostatic carcinoma are characteristically blastic, and may simulate Paget’s disease, es-
specially in the pelvis. Although all tumors may at times produce blastic metastases, most tumor metastases are lytic. Carci-
noma of the breast is sometimes mixed; carcinoma of the bladder, if it involves the prostate gland, may result in osteo-
blastic metastases. Occasionally, colo-
rectal carcinoma will produce blastic metastases with extensive calcification of associated soft tissue masses which strongly resemble osteogenic sarcoma or chondrosarcoma.

Kidney and thyroid carcinomas usually give rise to solitary, slow-growing metastases which grossly expand the bone. Metastatic cancer shows a predi-
lection for involvement of the vertebral pedicles; unlike myeloma, it tends to spare the mandible. Extensive skeletal involvement by metastatic disease often results in collapse of vertebral bodies, fractures of the ribs with soft tissue masses and, sometimes, generalized osteoporosis. If a lesion destroys two adja-
cent vertebral bodies across a disc space, it is more likely inflammatory than neo-
plastic in nature.

Lymphoma and Hodgkin’s disease commonly produce nonspecific, lytic deposits in bone, but sometimes result in blastic lesions. Neuroblastoma in in-
fants and young children often produces widely disseminated lytic lesions, and leukemia may give a similar appearance.

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