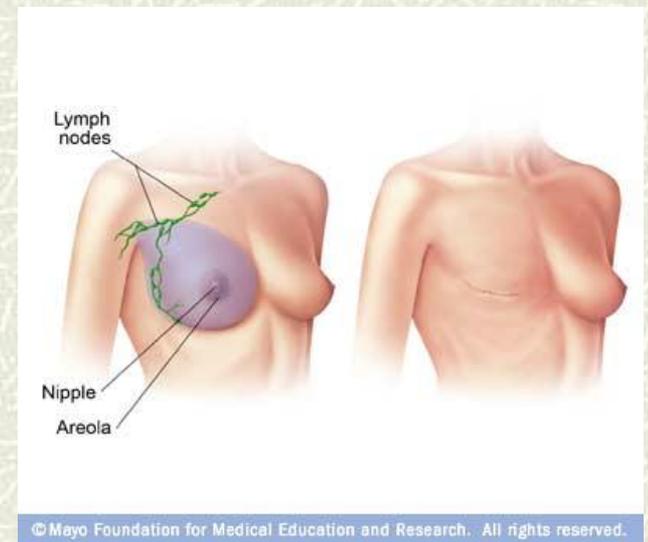




**Digital Mammography and  
Computer-Aided Diagnosis**

# Breast Cancer

- # Breast cancer is second only to lung cancer as a cause of cancer deaths in American women
- # One out of every seven women will be diagnosed with breast cancer in 2007
- # Fortunately, radical mastectomy (surgical removal) is rarely needed today with better treatment options



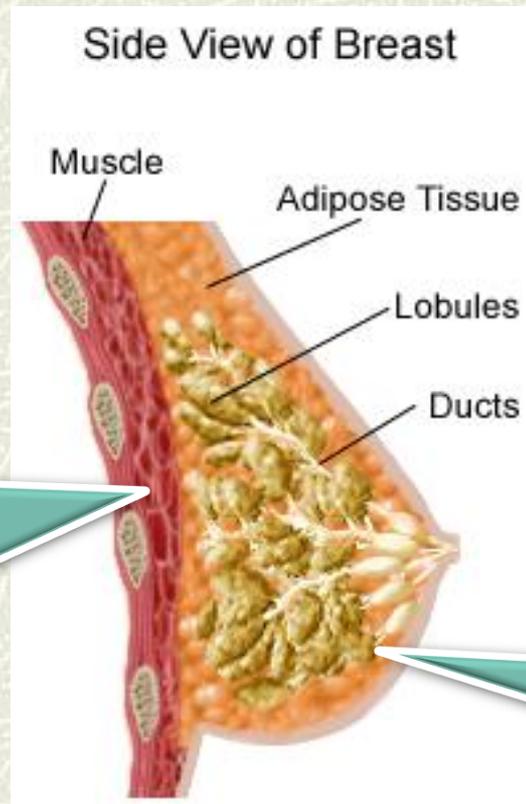
# Outline

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- # Female Breast Anatomy
- # Breast Cancer
- # Mammography
- # Computer-Aided Diagnosis of Breast Cancer

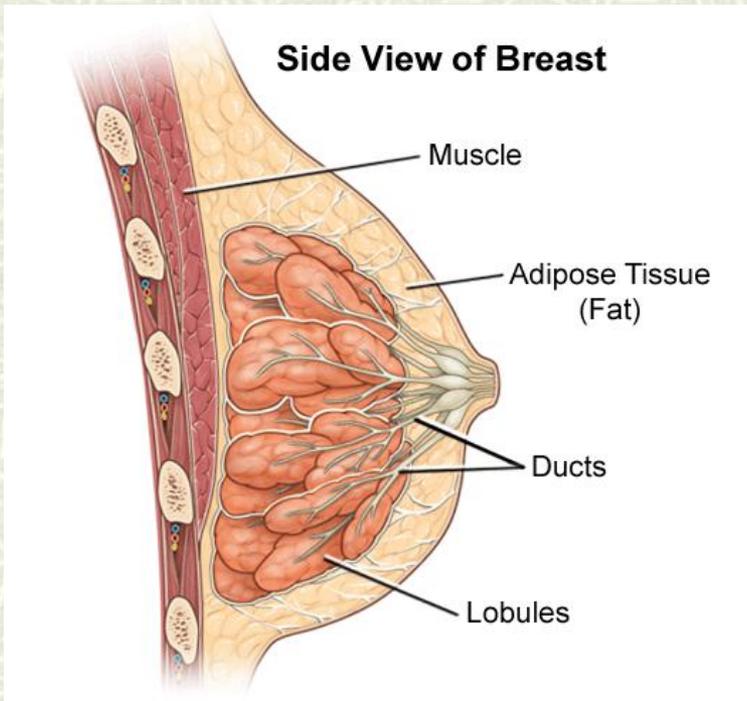
# Muscles

Muscles underneath the breasts separating them from the ribs



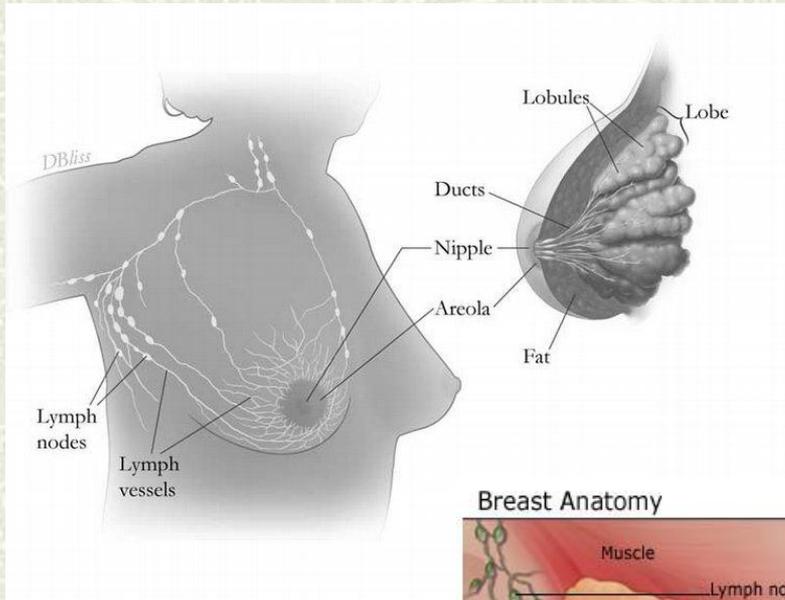
Breast has no muscle tissue

# Female Breast Anatomy



- # Breasts consist mainly of fatty tissue interspersed with connective tissue
- # There are also less conspicuous parts
  - lobes
  - ducts
  - lymph nodes

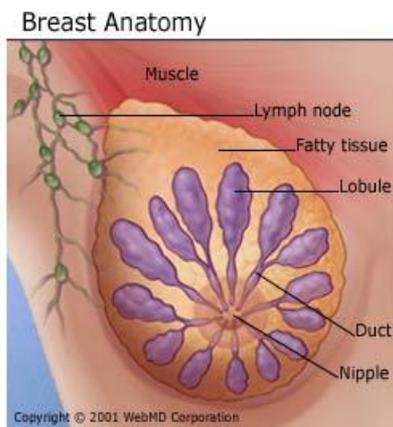
# Breast Gland



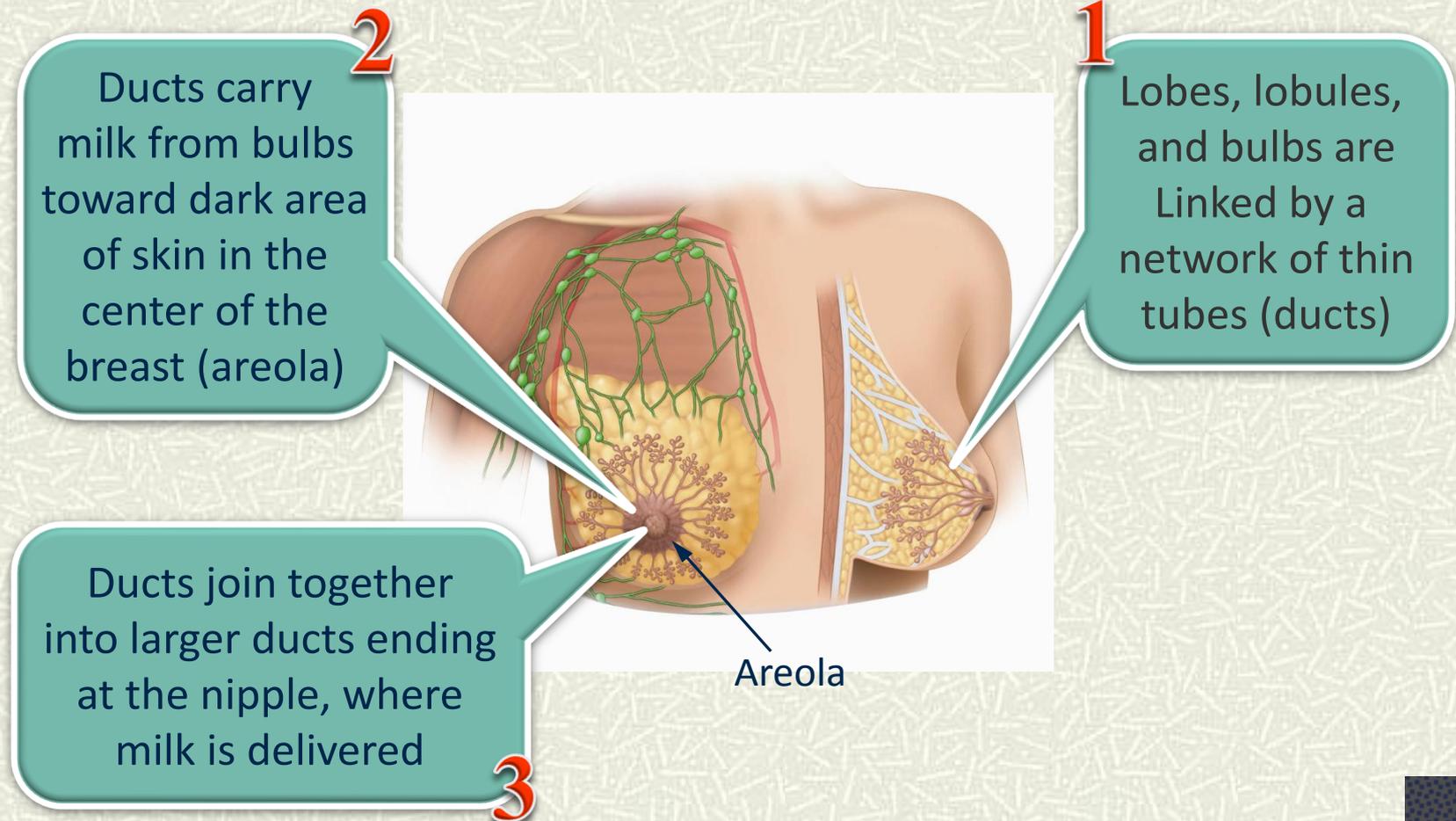
# Each breast has 15 to 20 sections (lobes) arranged like the petals of daisy

# Inside each lobe are many smaller structures called lobules

# At the end of each lobule are tiny sacs (bulbs) that can produce milk

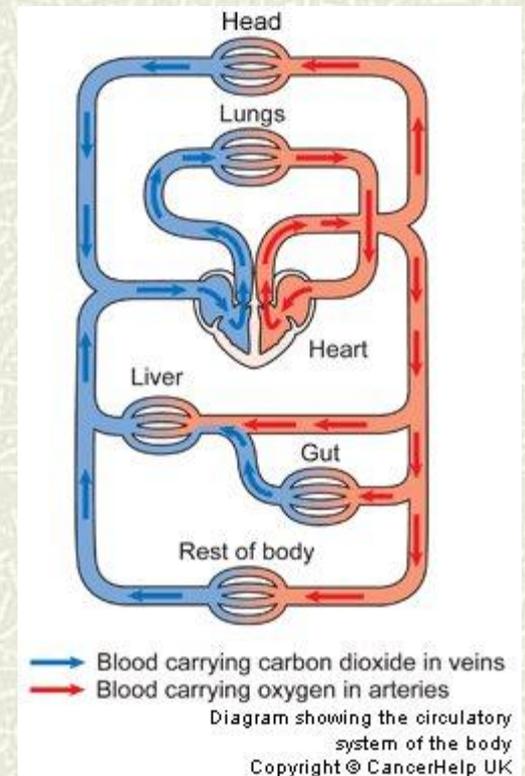
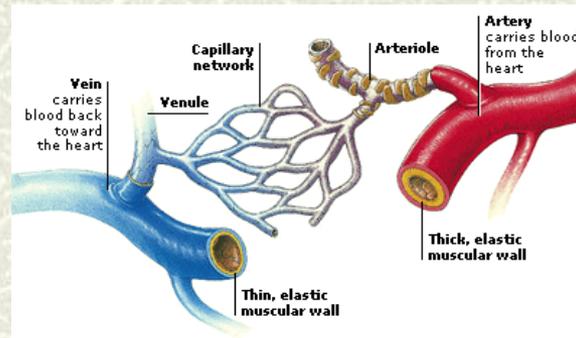


# Ducts

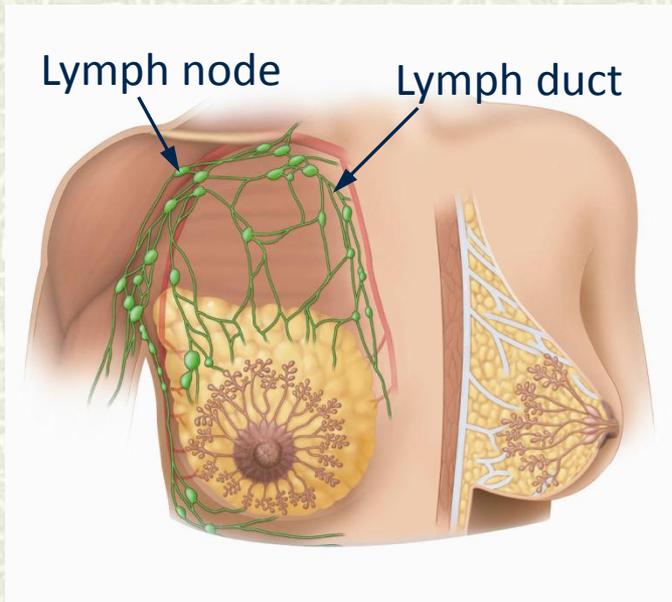


# Blood Vessels

Oxygen, nutrients, and other life-sustaining nourishment are delivered to breast tissue by the blood in the arteries and capillaries.



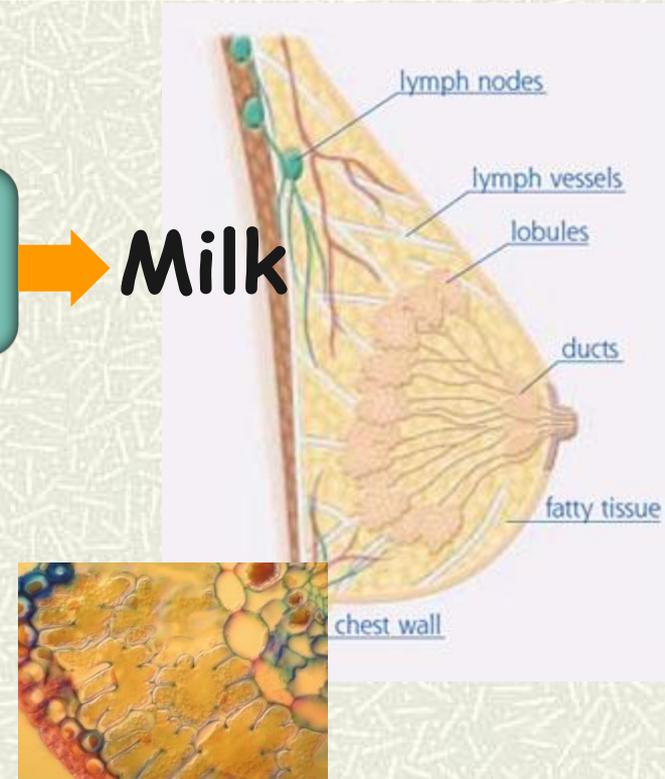
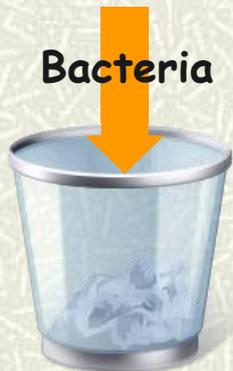
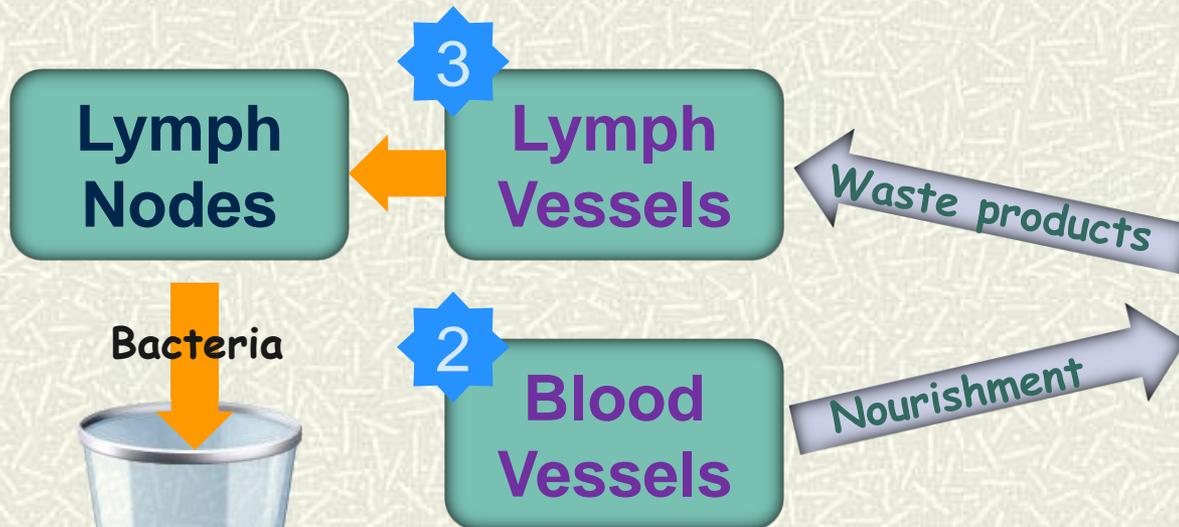
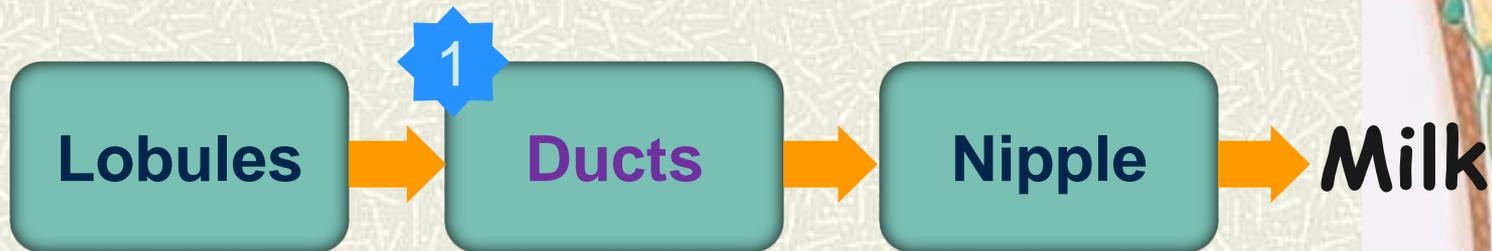
# Lymphatic System



A network of vessels

- # **Lymph ducts:** Drain fluid that carries white blood cells (that fight disease) from the breast tissues into lymph nodes under the armpit and behind the breastbone
- # **Lymph nodes:** Filter harmful bacteria and play a key role in fighting off infection

# Three Types of Vessels



# Signs and Symptoms

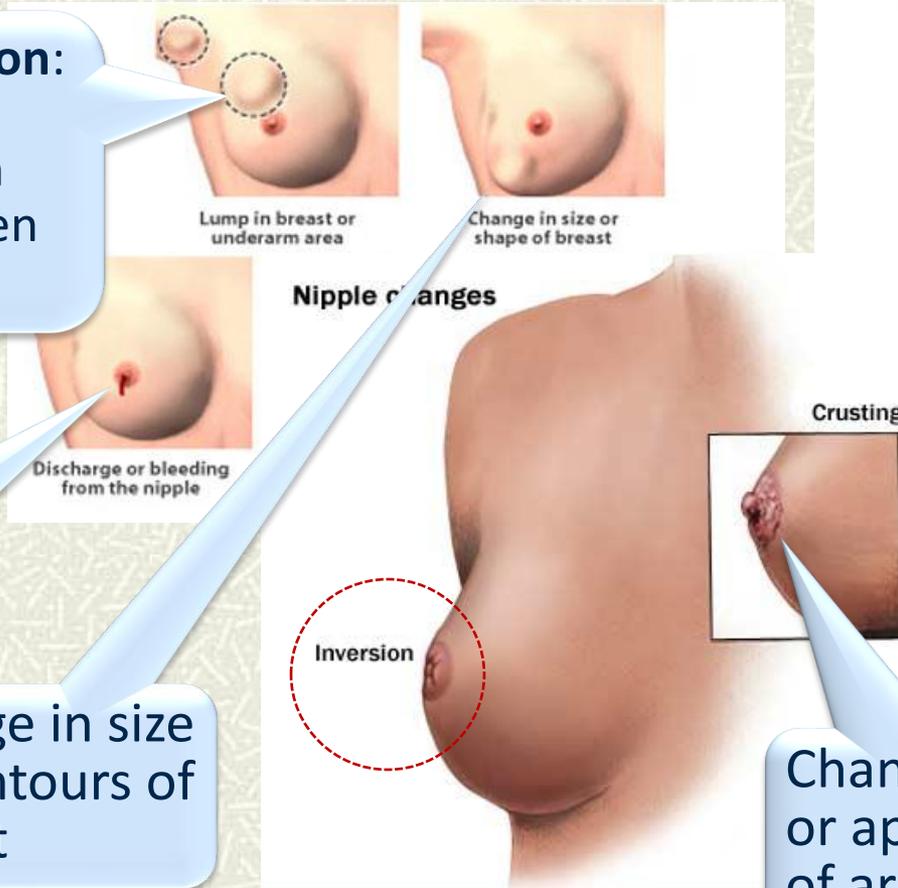
**Most common:**  
lump or thickening in breast. Often painless

Discharge or bleeding

Change in size or contours of breast

Change in color or appearance of areola

Redness or pitting of skin over the breast, like the skin of an orange



# Noncancerous Conditions (1)

---

- # **Fibrocystic changes:** Lumpiness, thickening and swelling, often associated with a woman's period
- # **Cysts:** Fluid-filled lumps can range from very tiny to about the size of an egg
- # **Fibroadenomas:** A solid, round, rubbery lump that moves under skin when touched, occurring most in young women
- # **Infections:** The breast will likely be red, warm, tender and lumpy
- # **Trauma:** a blow to the breast or a bruise can cause a lump

# Noncancerous Conditions (2)

---

- # **Microcalcifications:** Tiny deposits of calcium can appear anywhere in a breast and often show up on a mammogram
  - Most women have one or more areas of microcalcifications of various sizes
  - **Majority** of calcium deposits are **harmless**
  - A small percentage **may be precancerous or cancer** (biopsy is sometimes recommended)

# Causes

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- # Some of the cells begin growing abnormally
- # These cells divide more rapidly than healthy cells do and may spread through the breast, to the lymph or to other parts of the body (metastasize)
- # The most common type of breast cancer begins in the milk-production ducts, but cancer may also occur in the lobules or in other breast tissue

# Normal Breast

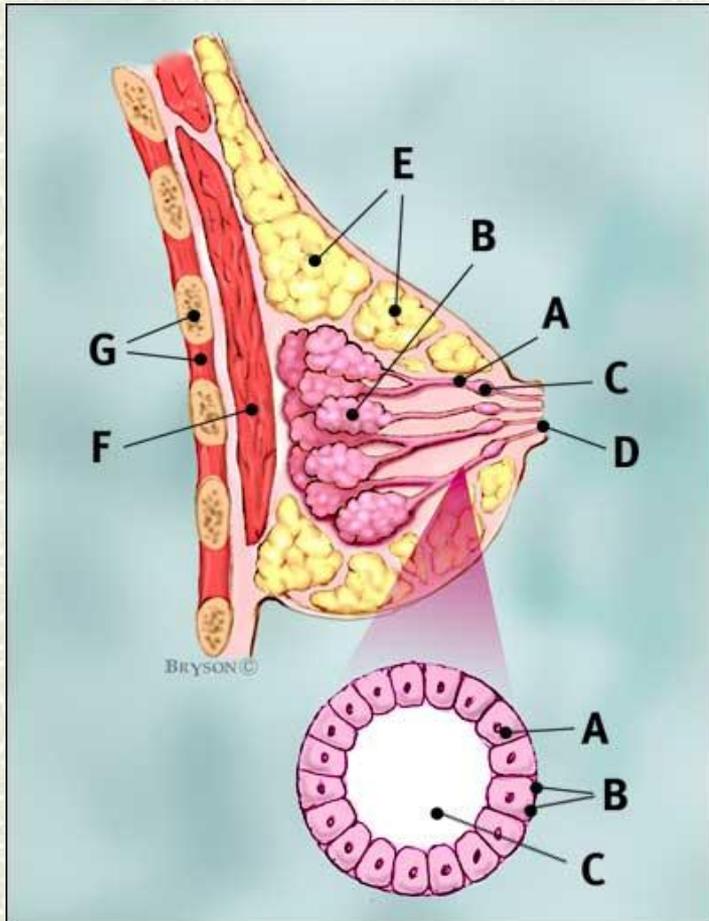


Illustration © Mary K. Bryson

## Breast profile

A	ducts
B	lobules
C	dilated section of duct to hold milk
D	nipple
E	fat
F	pectoralis major muscle
G	chest wall/rib cage

## Enlargement

A	normal duct cells
B	basement membrane (duct wall)
C	lumen (center of duct)

# Ductal Carcinoma in situ (DCIS)

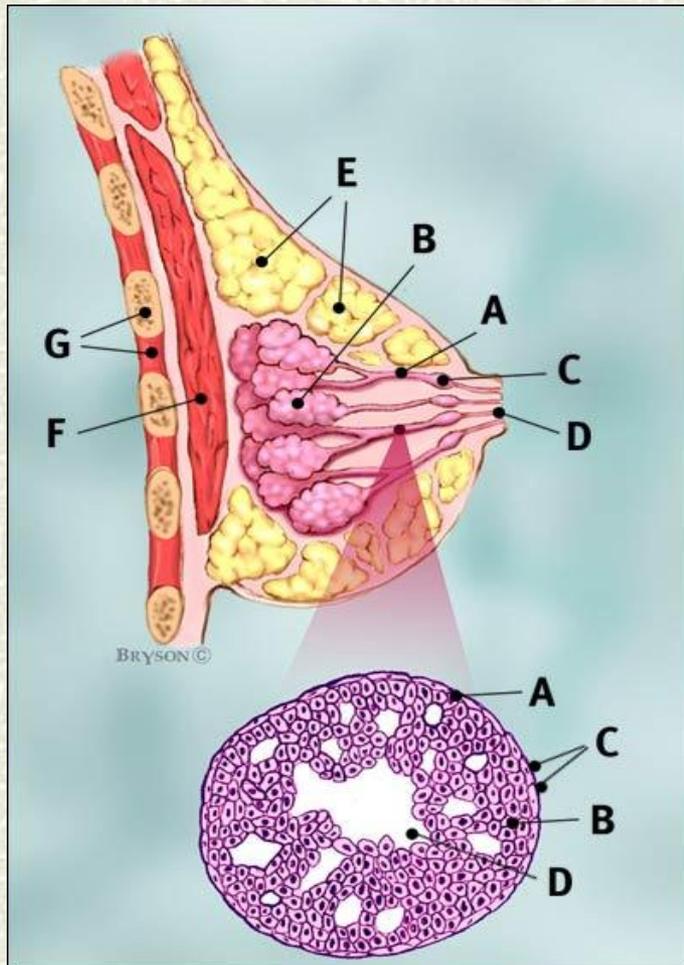
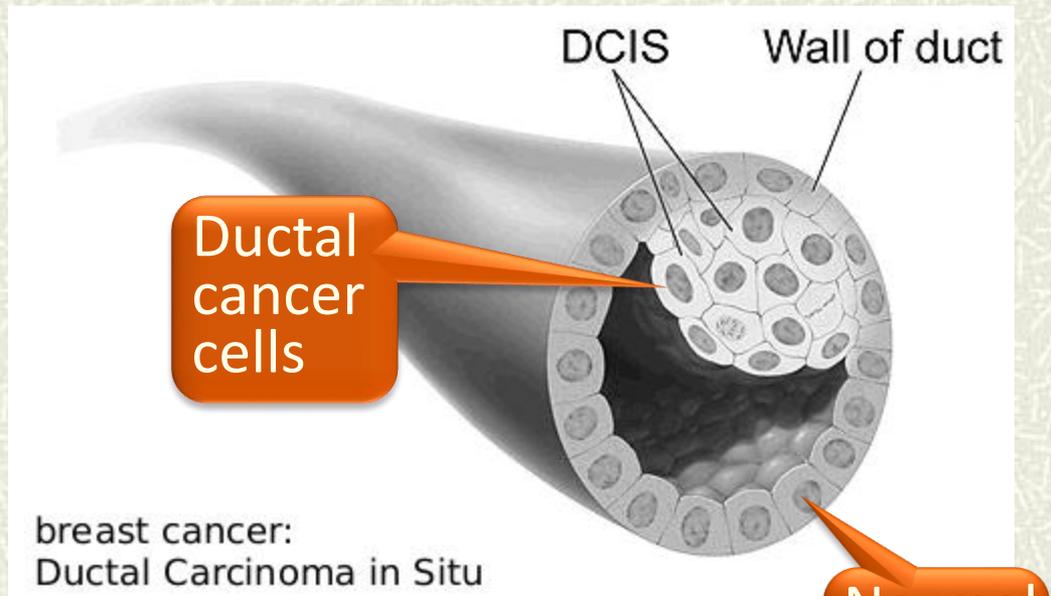


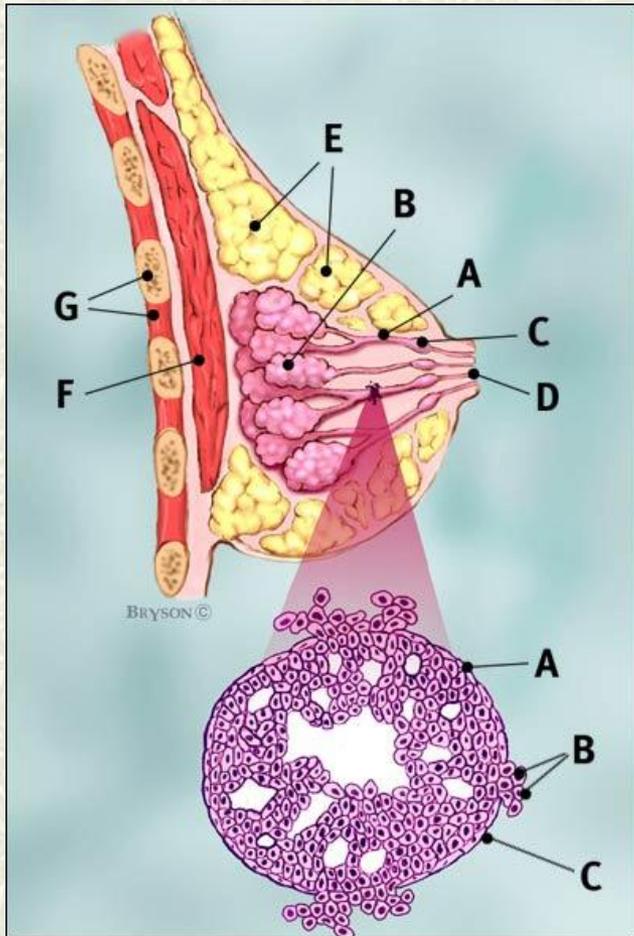
Illustration © Mary K. Bryson



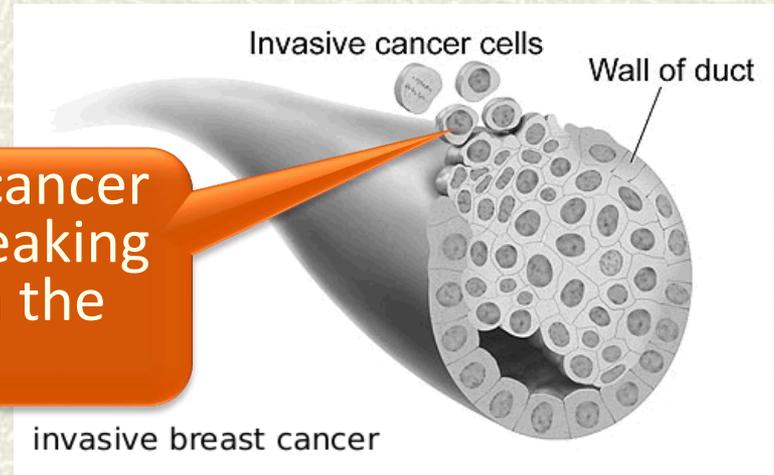
breast cancer:  
Ductal Carcinoma in Situ

**Carcinoma** refers to any cancer that begins in the skin or other tissues that cover internal organs

# Invasive Ductal Carcinoma (IDC - 80% of breast cancer)



Ductal cancer cells breaking through the wall



# The cancer has spread to the surrounding tissues

# Range of Ductal Carcinoma in situ

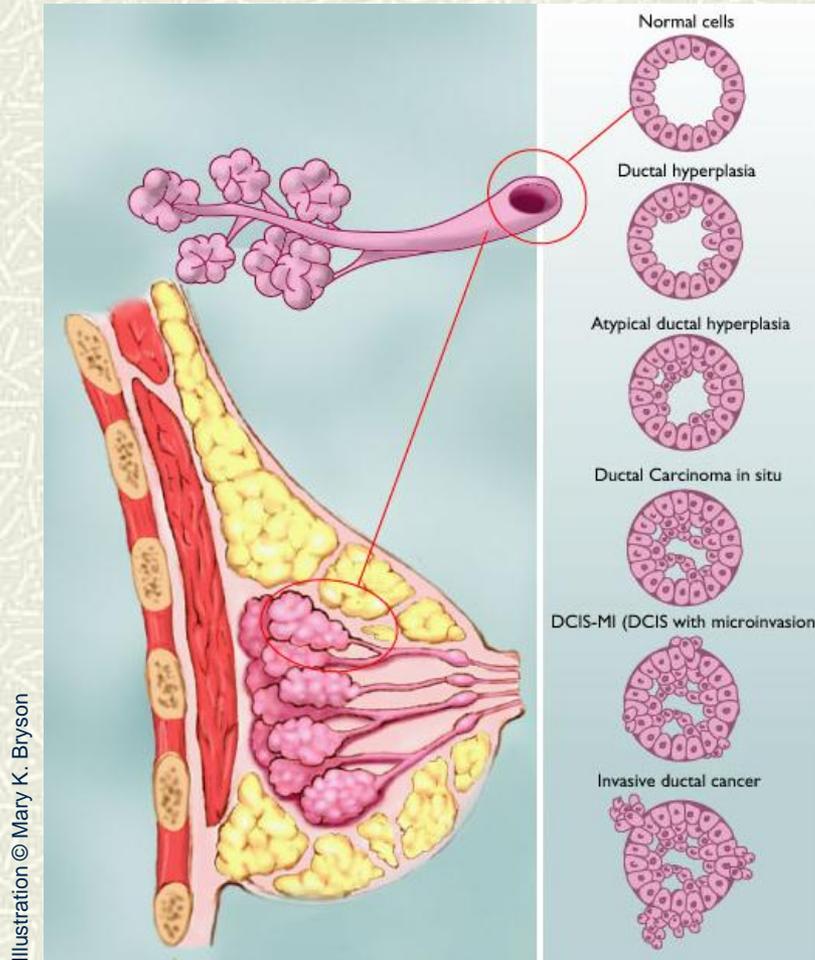
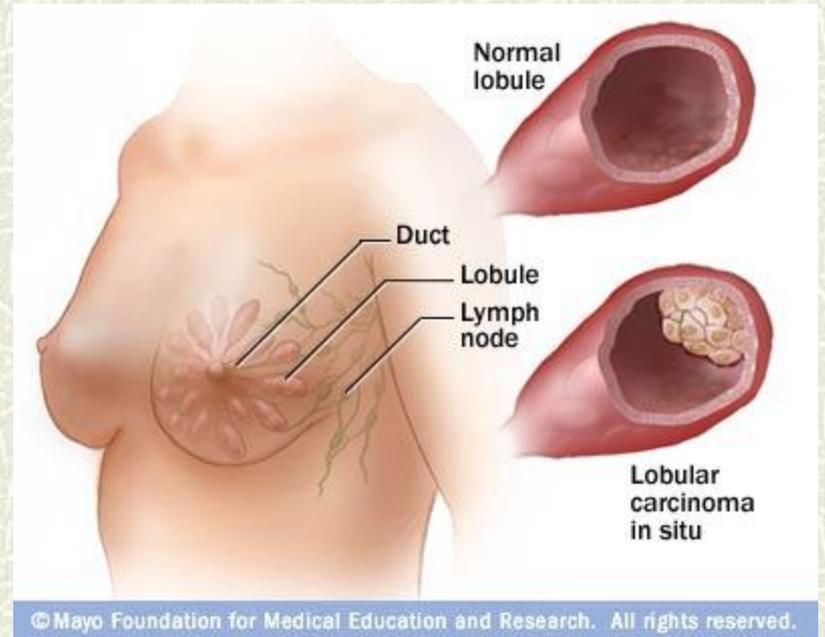
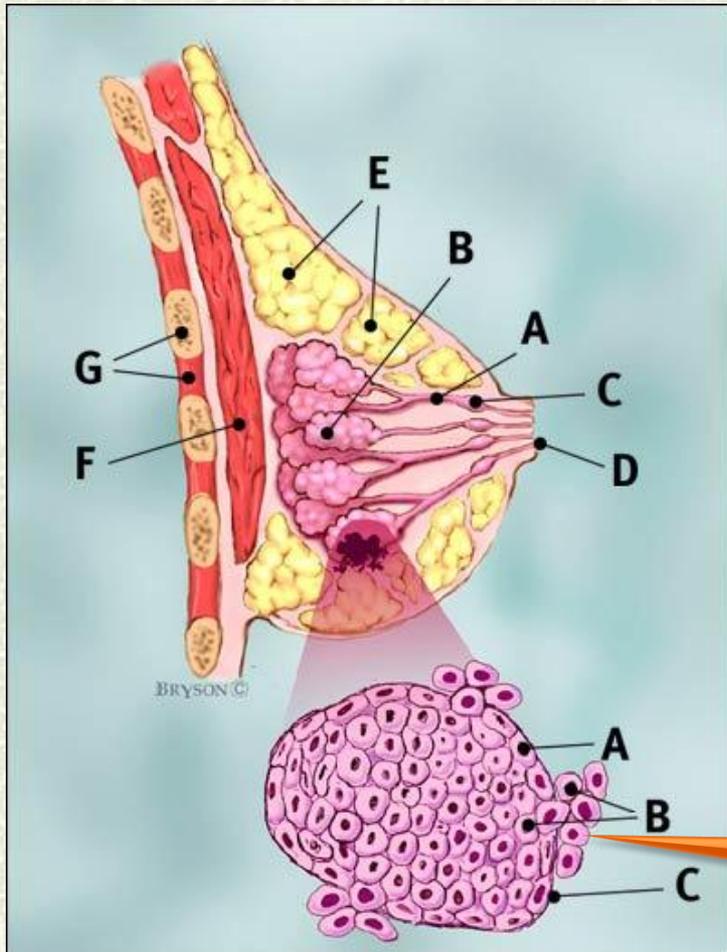


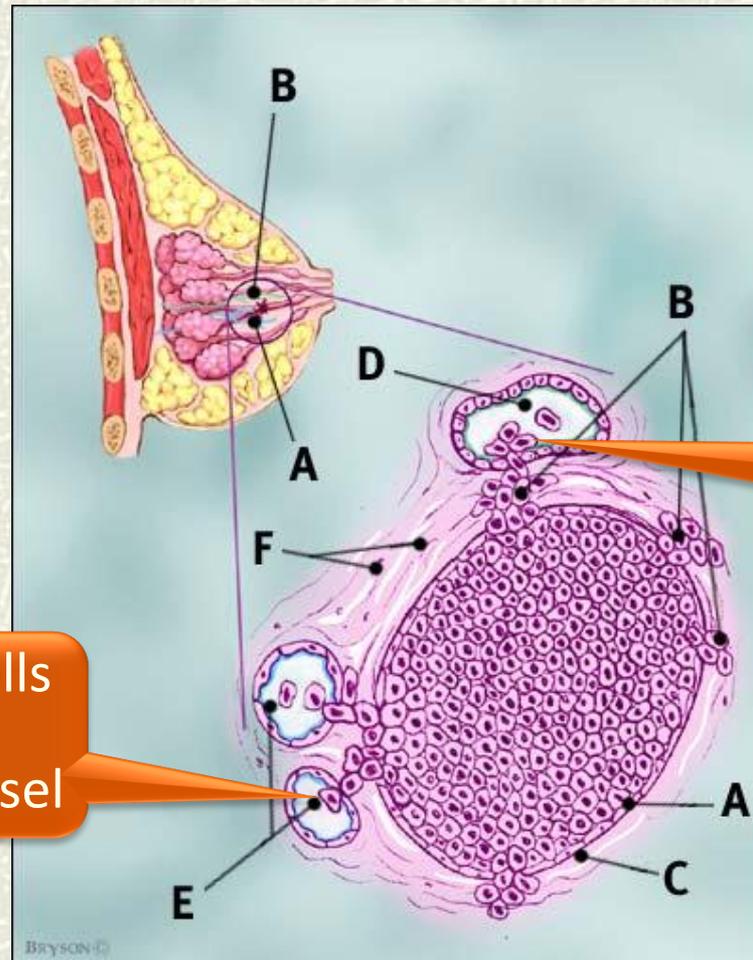
Illustration © Mary K. Bryson

# Invasive Lobular Carcinoma (ILC)



Lobular cancer cells breaking through the wall

# Cancer Can also Invade Lymph or Blood Vessels



Cancer cells invade blood vessel

Cancer cells invade lymph duct

# Mammography

- # Use a low-dose **x-ray** system to examine breasts
- # **Digital mammography** replaces **x-ray film** by **solid-state detectors** that convert x-rays into electrical signals. These signals are used to produce images that can be displayed on a computer screen (similar to digital cameras)
- # Mammography can show changes in the breast up to two years before a physician can feel them



# Computer-Aided Diagnosis

- ✦ Mammography allows for efficient diagnosis of breast cancers at an earlier stage
- ✦ Radiologists misdiagnose 10-30% of the malignant cases
- ✦ Of the cases sent for surgical biopsy, only 10-20% are actually malignant

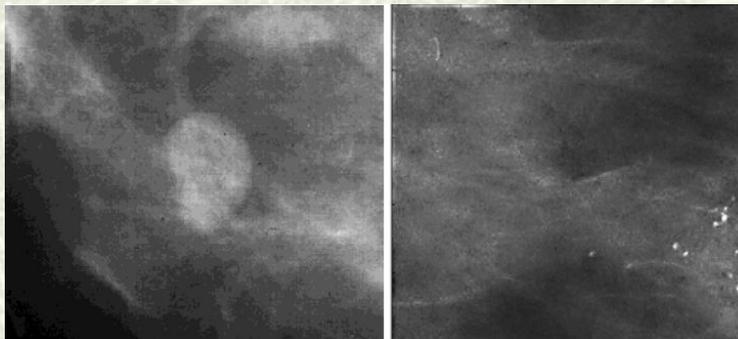
CAD systems  
can assist  
radiologists to  
Reduce these  
problems

# What Mammograms Show

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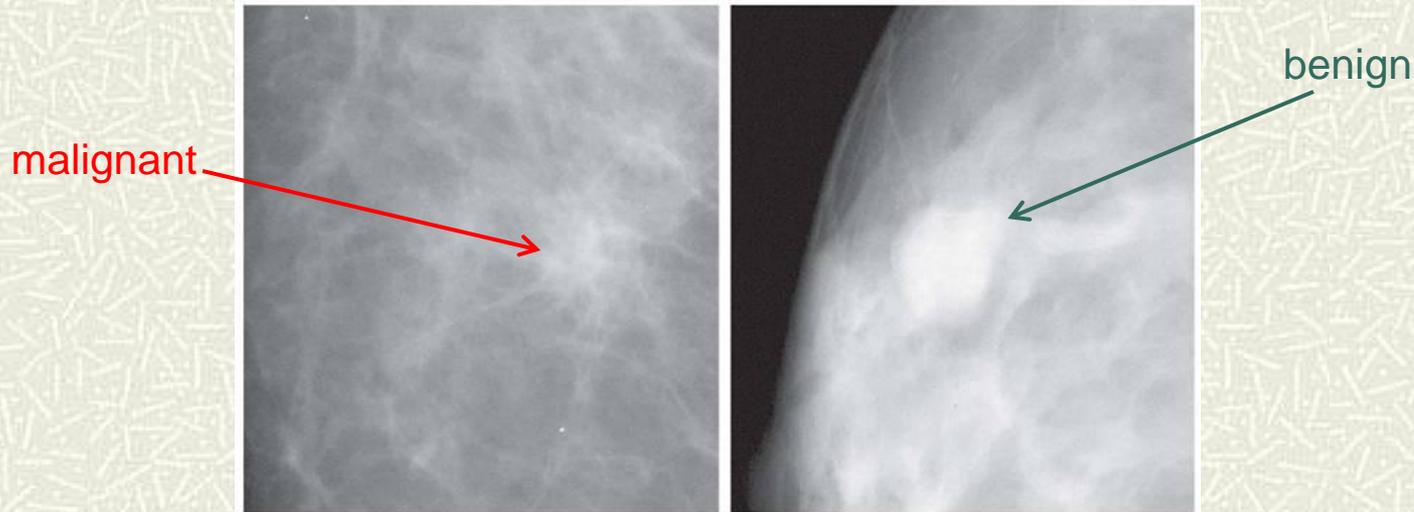
Two of the most important mammographic indicators of breast cancers

- **Masses**
- **Microcalcifications:** Tiny flecks of calcium - like grains of salt - in the soft tissue of the breast that can sometimes indicate an early cancer.

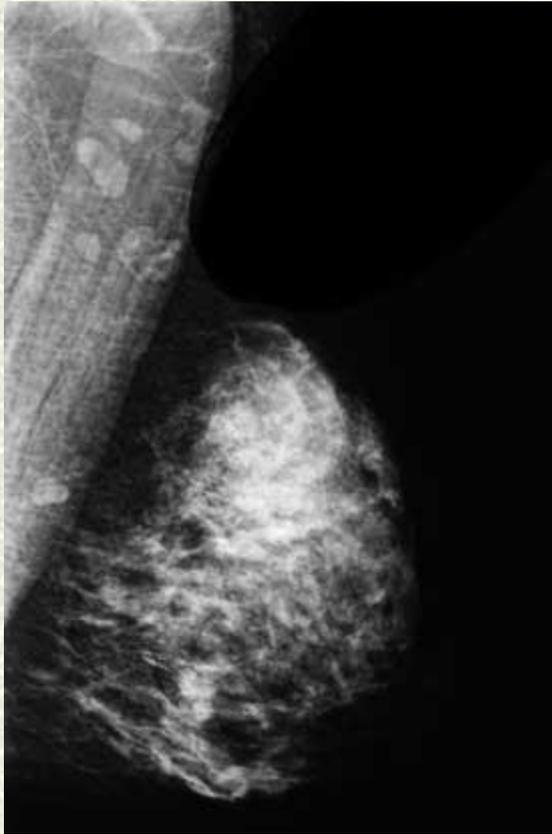


# Detection of Malignant Masses

Malignant masses have a more **spiculated** appearance

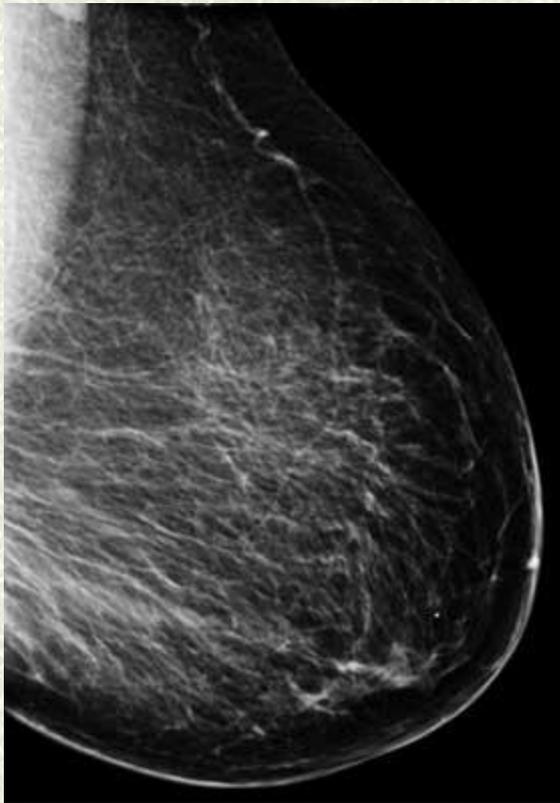


# Mammogram - Difficult Case



- # Heterogeneously dense breast
- # Cancer can be difficult to detect with this type of breast tissue
- # The fibroglandular tissue (white areas) may hide the tumor
- # The breasts of younger women contain more glands and ligaments resulting in dense breast tissue

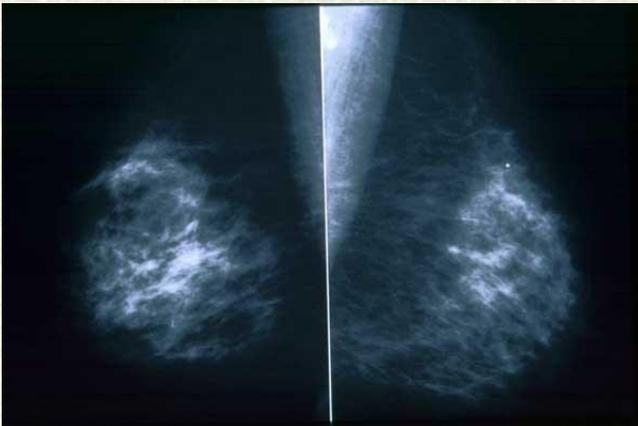
# Mammogram - Easier Case



- # With age, breast tissue becomes fattier and has fewer glands
- # Cancer is relatively easy to detect in this type of breast tissue

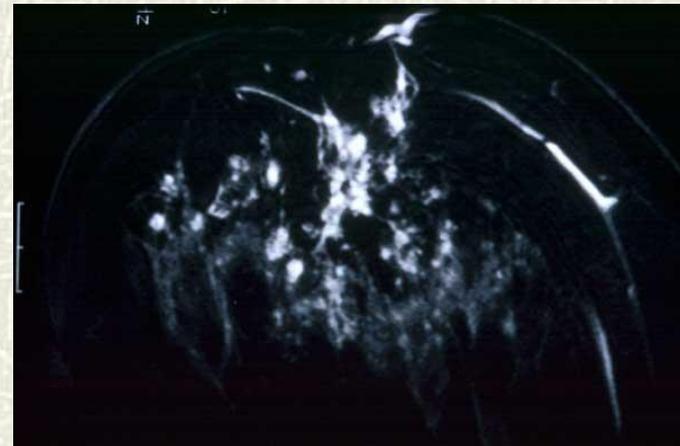
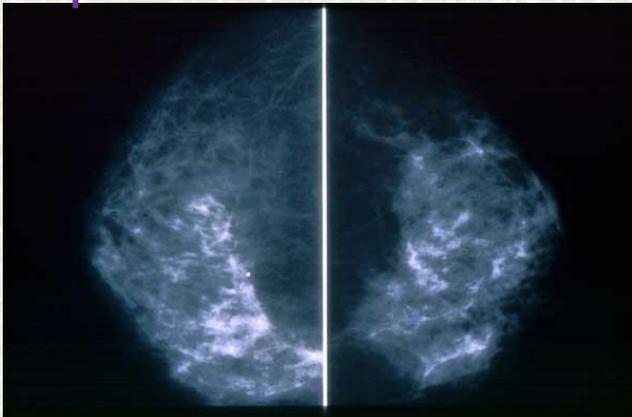
# Different Views

Side-to-Side



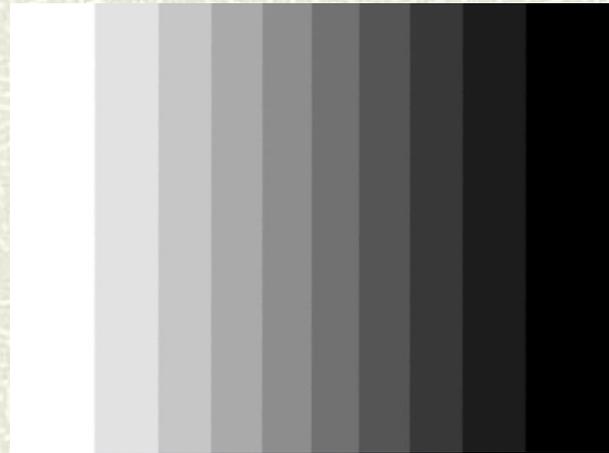
MRI - Cancer can have a unique appearance – many small irregular white areas that turned out to be cancer (used for diagnosis)

Top-to-Bottom



# Scalar Field

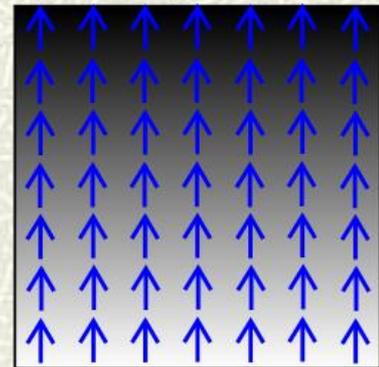
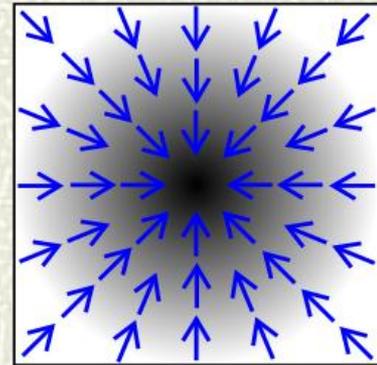
- # A *scalar field* is a  $n$ -dimensional space with a scalar value attached to each point in the space (e.g., a gray-scale image)



# Scalar Field and Gradient

- # A *scalar field* is a n-dimensional space with a scalar value attached to each point in the space (e.g., a gray-scale image)
- # The derivative of a scalar field results in a vector field called the *gradient*
  - i.e., the gradient is a vector field
    - which points in the **direction** of the greatest rate of increase of the scalar field, and
    - whose **magnitude** is the greatest rate of change

Black representing  
Higher values

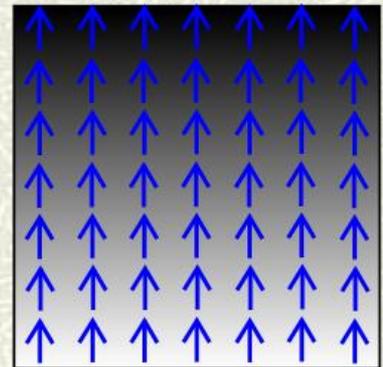
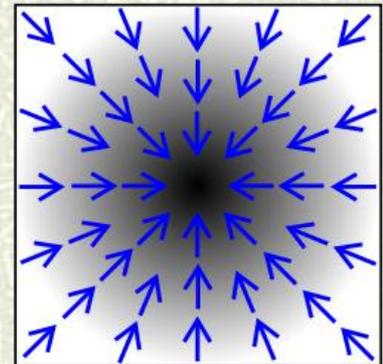


# Gradient

The derivative of a scalar field results in a vector field called the *gradient*

- i.e., the gradient is a vector field
  - which points in the **direction** of the greatest rate of increase of the scalar field, and
  - whose **magnitude** is the greatest rate of change

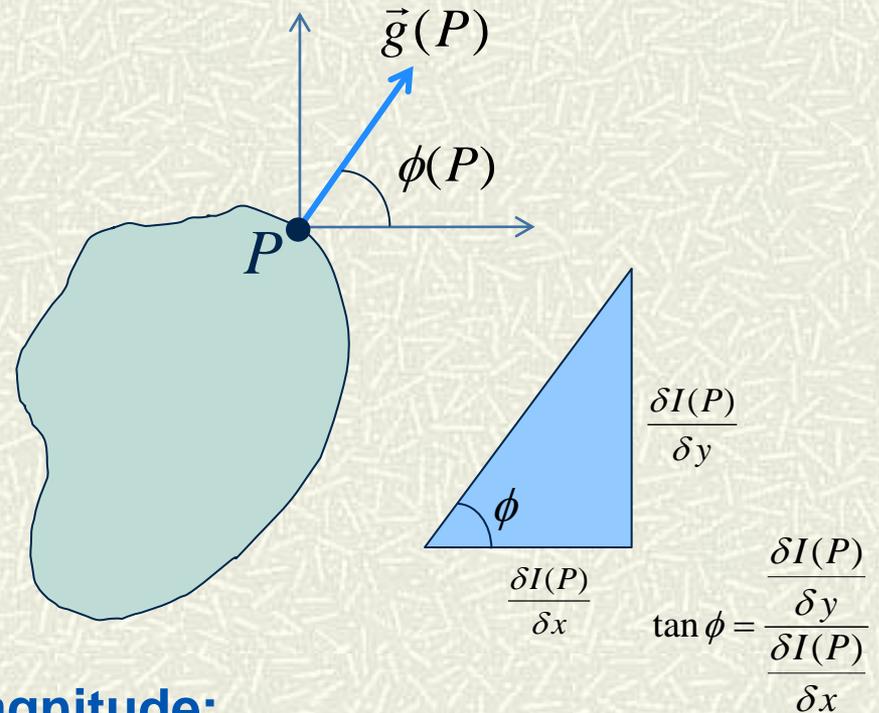
Black representing  
Higher values



# Cartesian Gradient

For an image function  $I(P)$  where  $P$  is a pixel, the Cartesian gradient at  $P$  is:

$$\vec{g}(P) = \begin{bmatrix} \frac{\partial I(P)}{\partial x} \\ \frac{\partial I(P)}{\partial y} \end{bmatrix}$$



**Orientation:**

$$\phi(P) = \arctan \left( \frac{\frac{\partial I(P)}{\partial y}}{\frac{\partial I(P)}{\partial x}} \right)$$

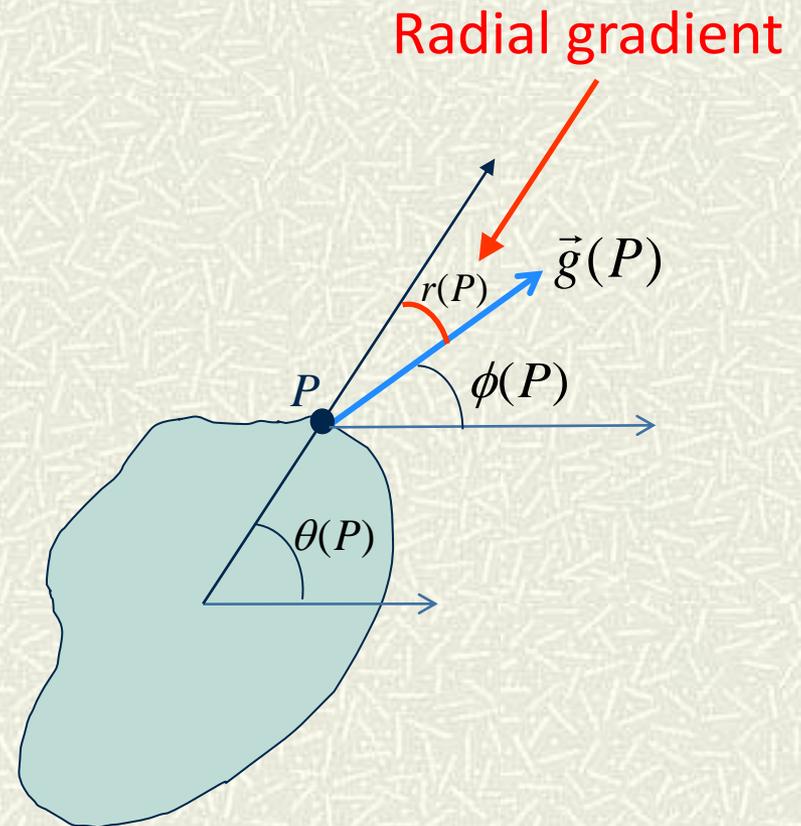
**Magnitude:**

$$m(P) = \sqrt{\left[ \frac{\partial I(P)}{\partial x} \right]^2 + \left[ \frac{\partial I(P)}{\partial y} \right]^2}$$

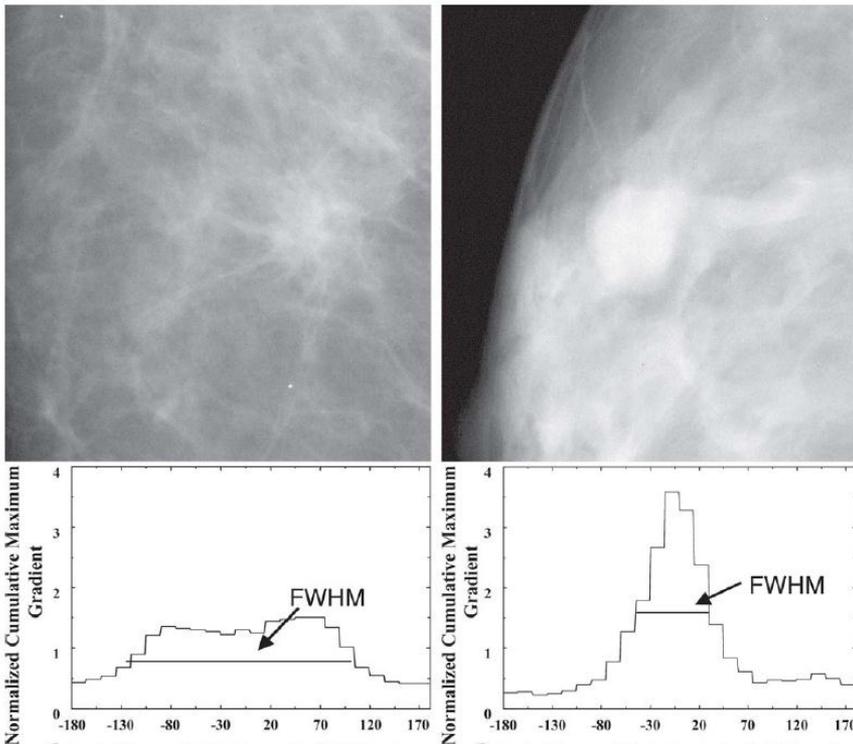
# Radial Gradient

- The radial gradient vector has the same magnitude as the Cartesian gradient vector, but
- the orientation is given as:

$$r(P) = \theta(P) - \phi(P)$$

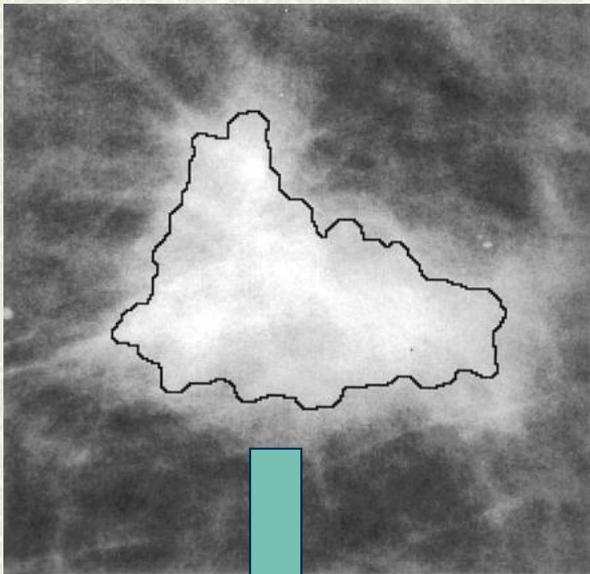


# Feature: Spiculation [Huo et al.]



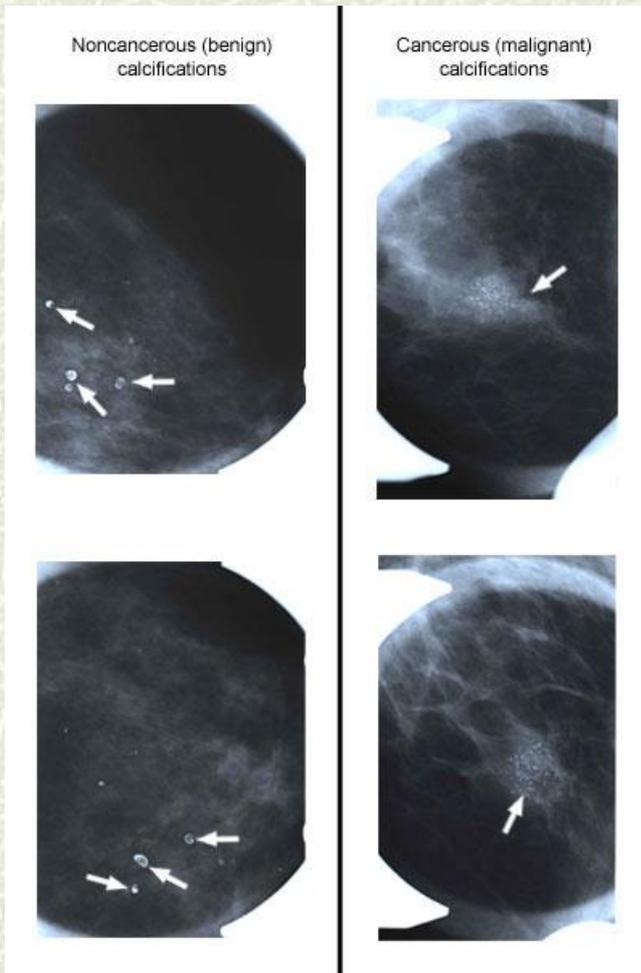
- # Extract the mass using a region-growing technique
- # The maximum gradient and its angle relative to the radial direction are computed
- # Calculate the full-width at half-maximum (FWHM) from the cumulative gradient orientation histogram

# Feature: Spiculation [Chan et al.]



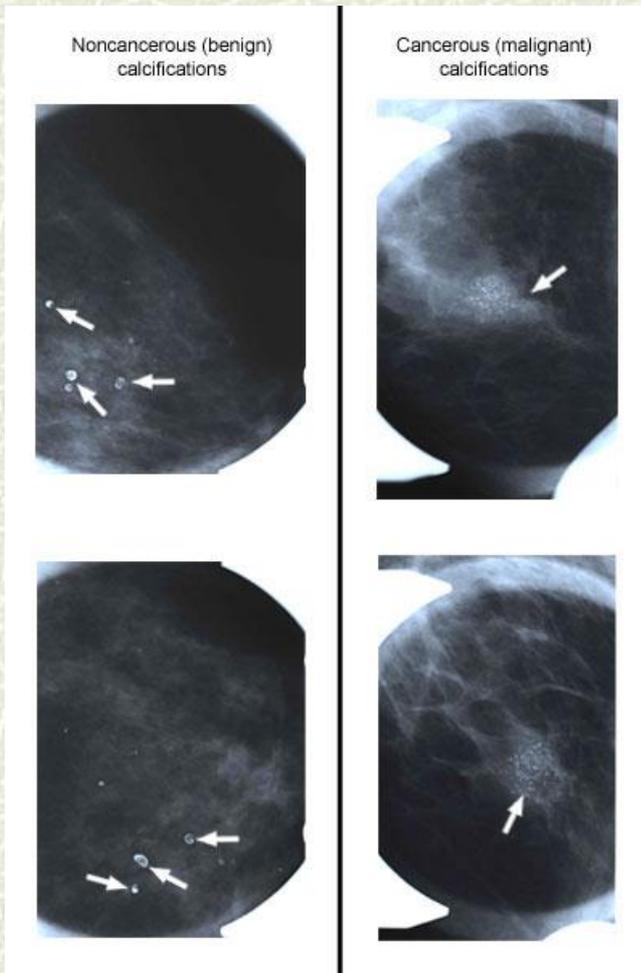
- # Determine the outline of the segmented mass
- # Obtain the rubber-band-straightening-transformed image
  - The spicules become approximately aligned in a similar direction
- # The rectangular region can then be subjected to texture analysis

# Breast Calcifications



- ⌘ Calcifications show up as white spots on a mammogram
- ⌘ Round well-defined, larger calcifications (left column) are more likely benign
- ⌘ Tight cluster of tiny, irregularly shaped calcifications (right column) may indicate cancer

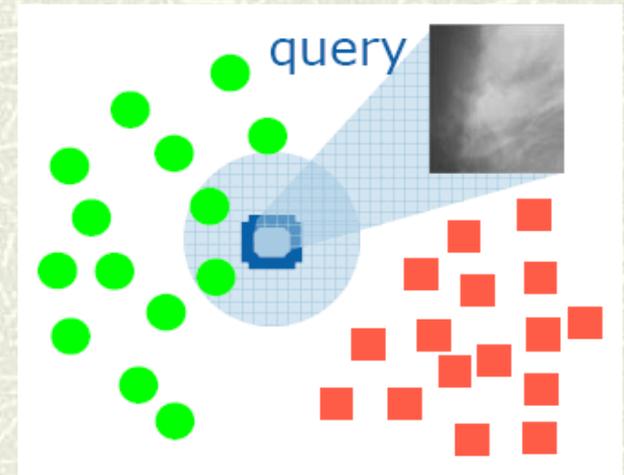
# Calcification Features



- # The **morphology** of individual calcification, e.g., shape, area, and brightness
- # The **heterogeneity** of individual features characterized by the mean, the standard deviation, and the maximum value for each feature.
- # **Cluster features** such as total area, compactness

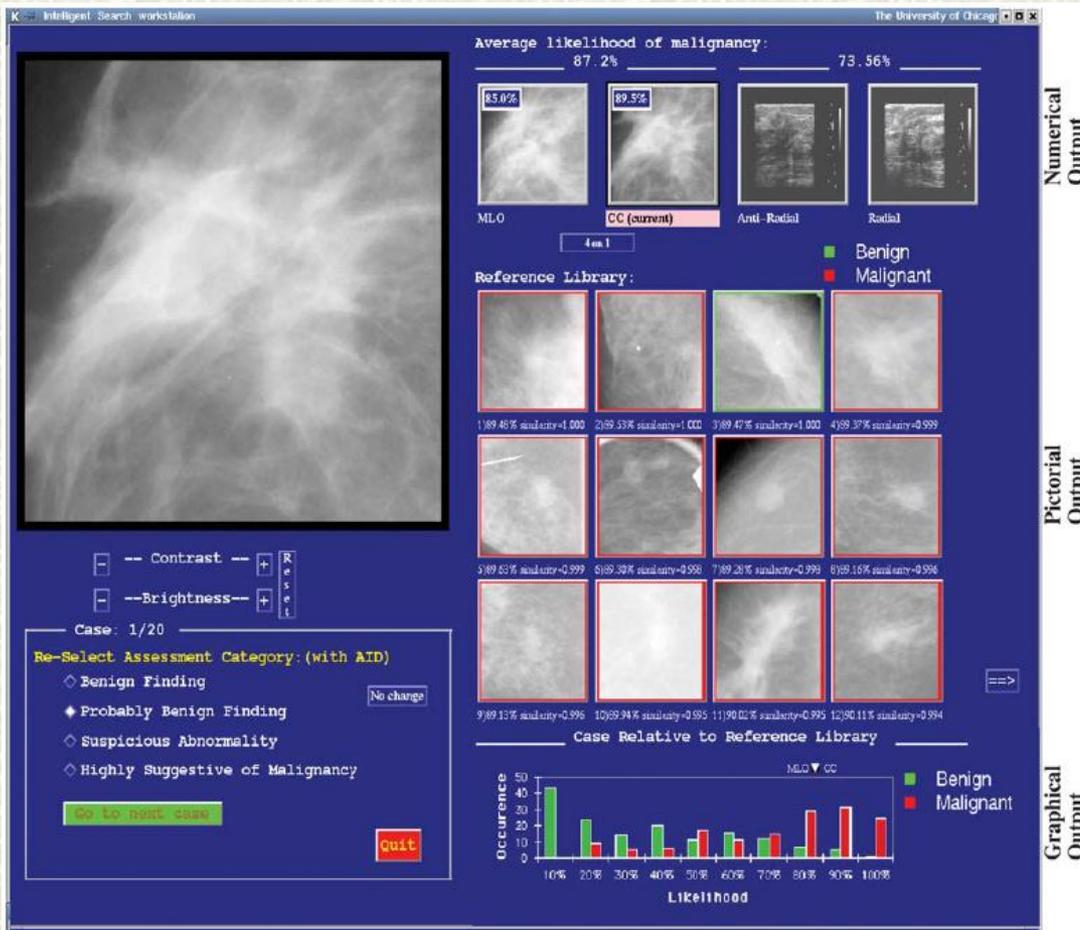
# Database Approach to Computer-Aided Diagnosis

- # Content-based image retrieval techniques can provide radiologists "visual aids" to increase confidence in their diagnosis
- # The database consists of a large number of images with verified pathology results
- # Diagnosis is done by submitting the suspected mass region as a query to retrieve similar cases from the database



# A Mammography CAD System

[Giger et al.]



Numerical Output

Probability of malignancy

Similar images of known diagnosis

Pictorial Output

Indicates the unknown lesion relative to all lesions in the database

Graphical Output