שינויים מולקולאריים ומבניים באי ספיקת לב
אפשרויות לטיפול עתידני

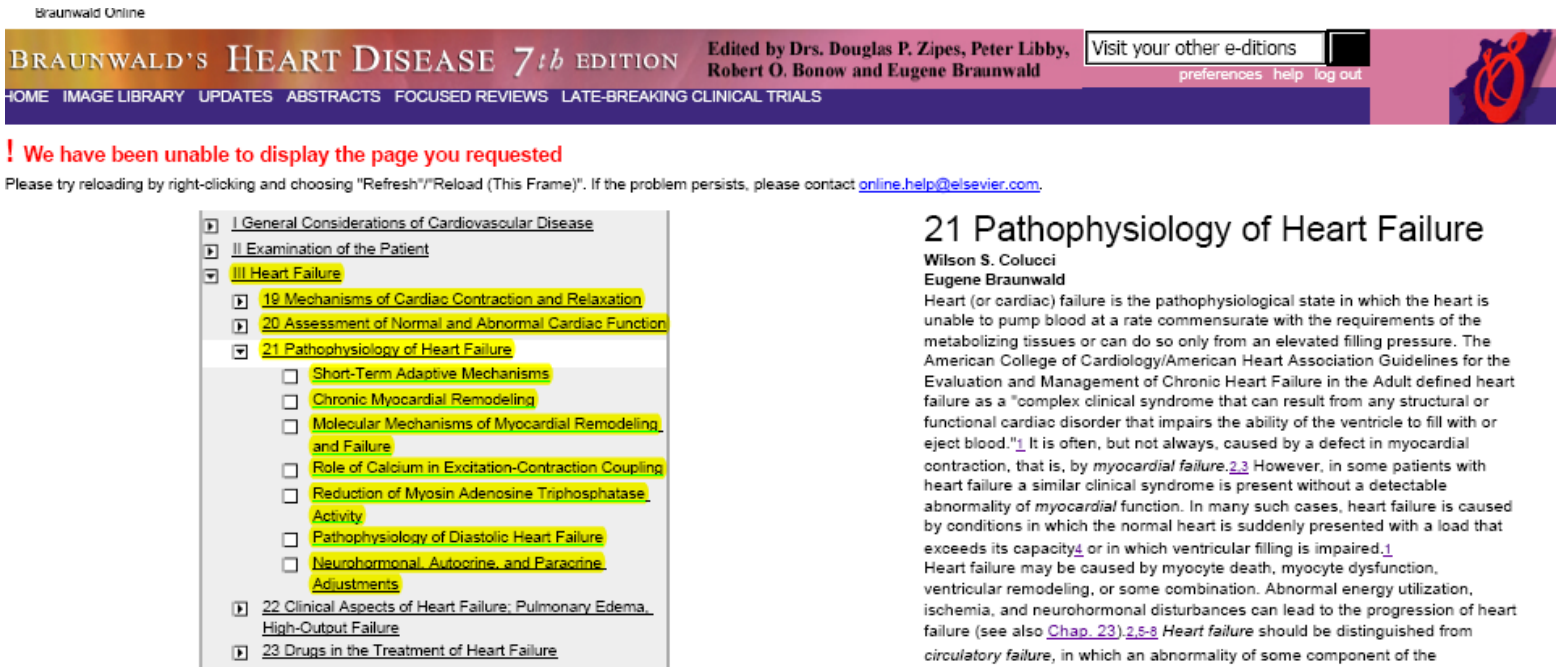
פרופ יהונתן ליאור

Braunwald's Heart Disease 8th Edition

Chapter 21 Mechanisms of Cardiac Contraction and Relaxation

Chapter 22 Pathophysiology of Heart failure

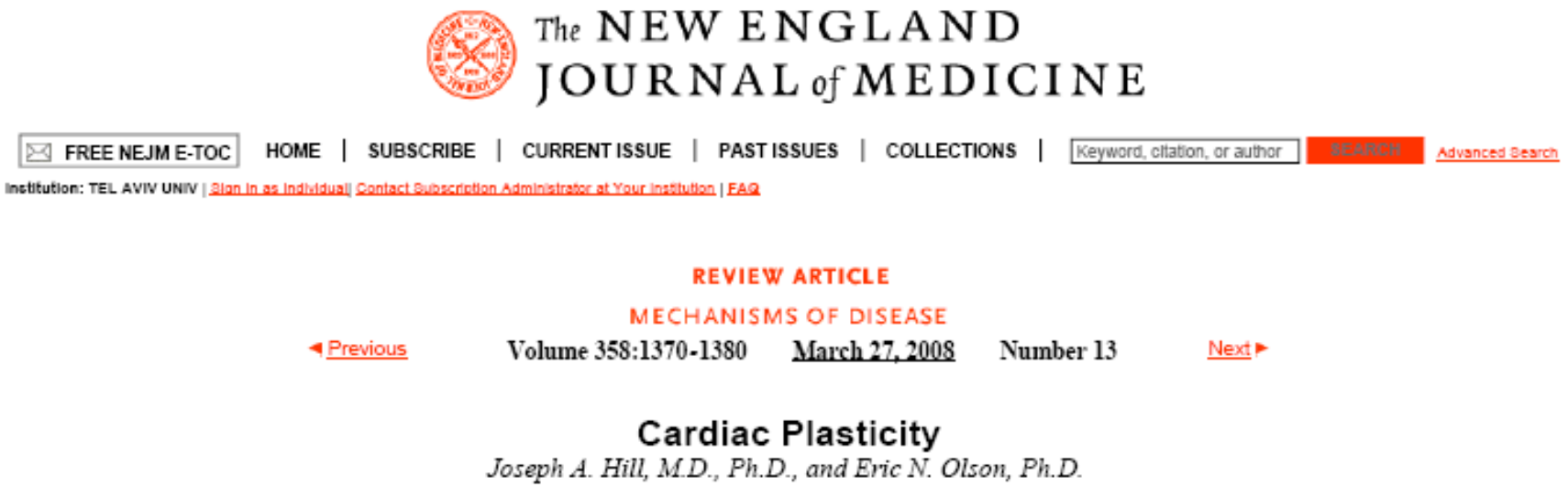
Chapter 29 Emerging therapies



ספרות

Cardiac Plasticity

Joseph A. Hill, M.D., Ph.D., and Eric N. Olson, Ph.D
N Eng J Med Volume 358:1370-1380 March 27, 2008



שאלה
מדידה שלו בדם 6 שעות מהסמנים ומנבאת פרוגנוזה לאחר אוטם שריר הלב (ברנוולד פרק 22)

1. טרופונין T
2. טרופונין I
3. נטריורטיק פפטיד
4. קולגן

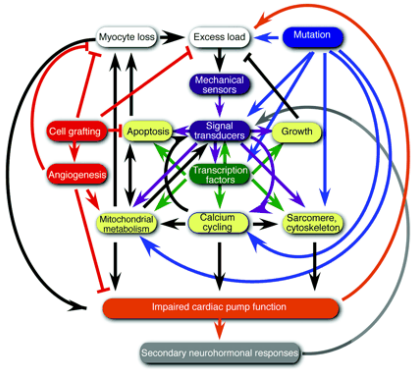
שאלה

מתן מעכבי ACE יעכב הכל למעט (סמן תשובה לא נכונה)

1. **Beta-adrenergic desensitization**
2. **Fetal gene expression**
3. **Myocyte necrosis**
4. **MMP activation**
5. **E-C coupling**

Main Topics

1. LV remodeling -cellular and molecular level
2. Extracellular matrix
3. Regeneration



Myocardium

1. Cardiomyocytes and non-myocyte cells
2. Extracellular Matrix
3. Vessels

Myocardial Cells

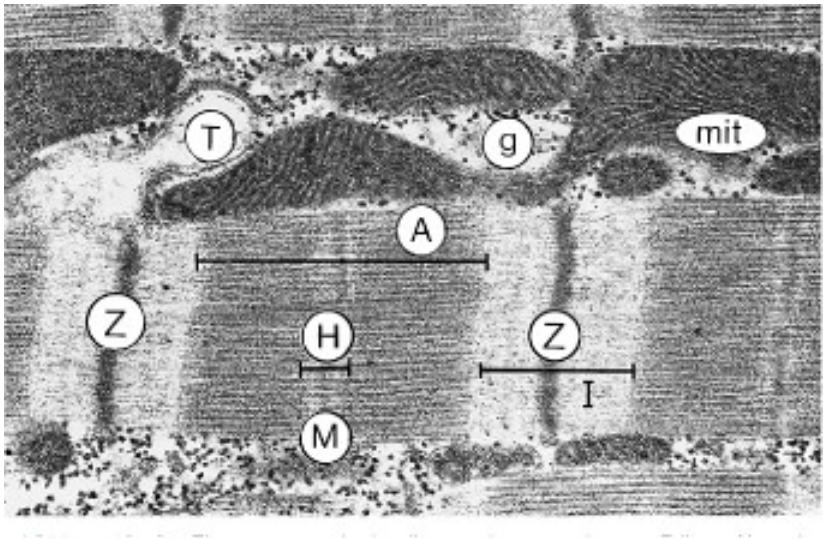
TABLE 1. Myocytes and Nonmyocytes in the Myocardium

Group	By Cell No.	By Cell Volume	By Cell Mass
Cardiomyocyte	25%[18]	≈75%[18]	...
	30–35% [19]	≈67%[6]	≈90%[17,20]
	33% [6]	67%[22]	...
		80%[23]	...
Nonmyocyte	75%*[18]	≈33%[6]	≈10%[17,20,21]
	65–70% [19]	33%†[22]	(90–95% fibroblasts)‡[17,20]
	67% [6]	20% (13% vascular)§[23]	...

*Connective tissue nuclei.
§Includes lumen (volume fraction).
†Mostly fibroblasts.
‡Fibroblasts as % of nonmyocyte fraction.

Jugdutt & al. Circulation 2003

The Sarcomere



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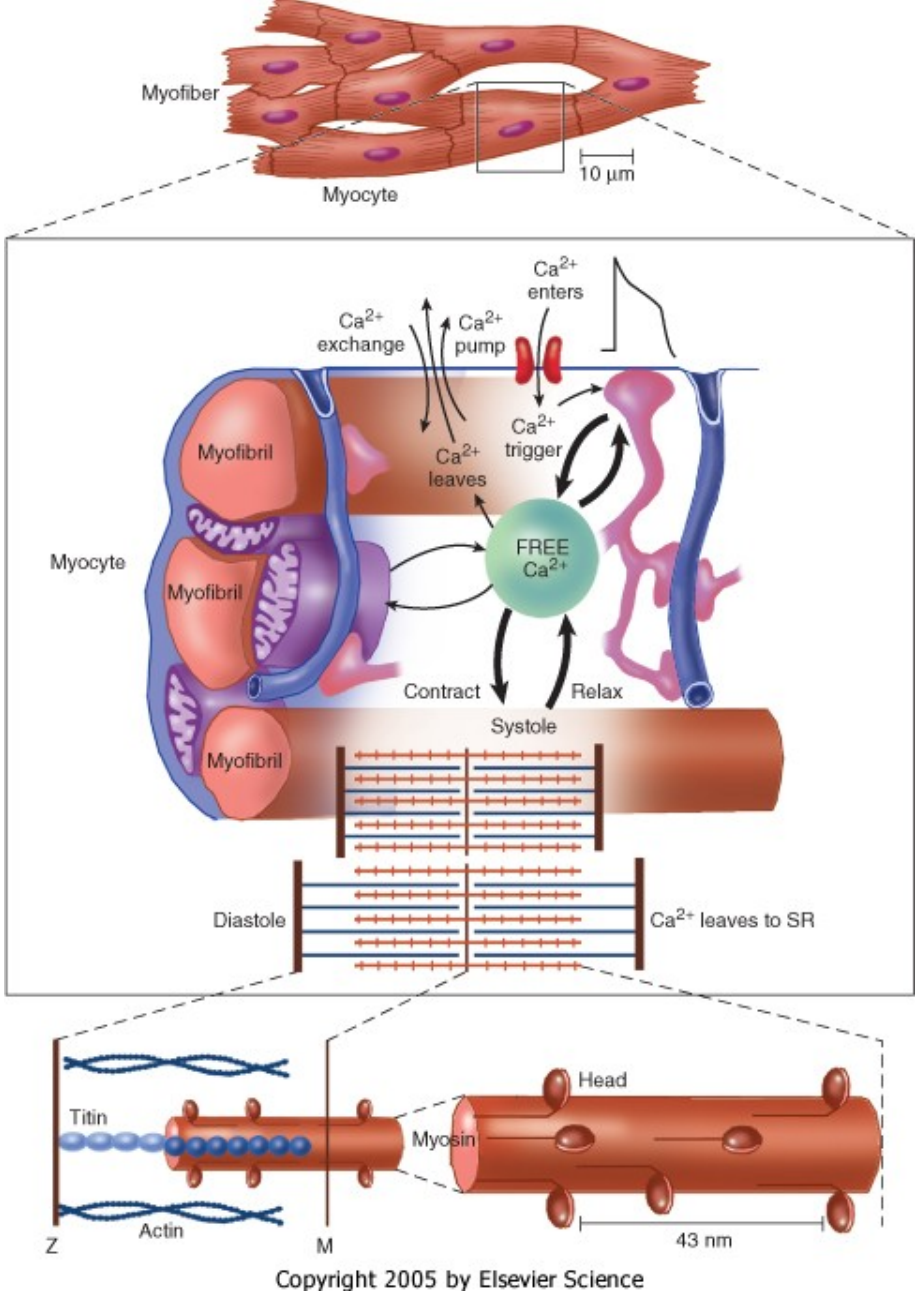

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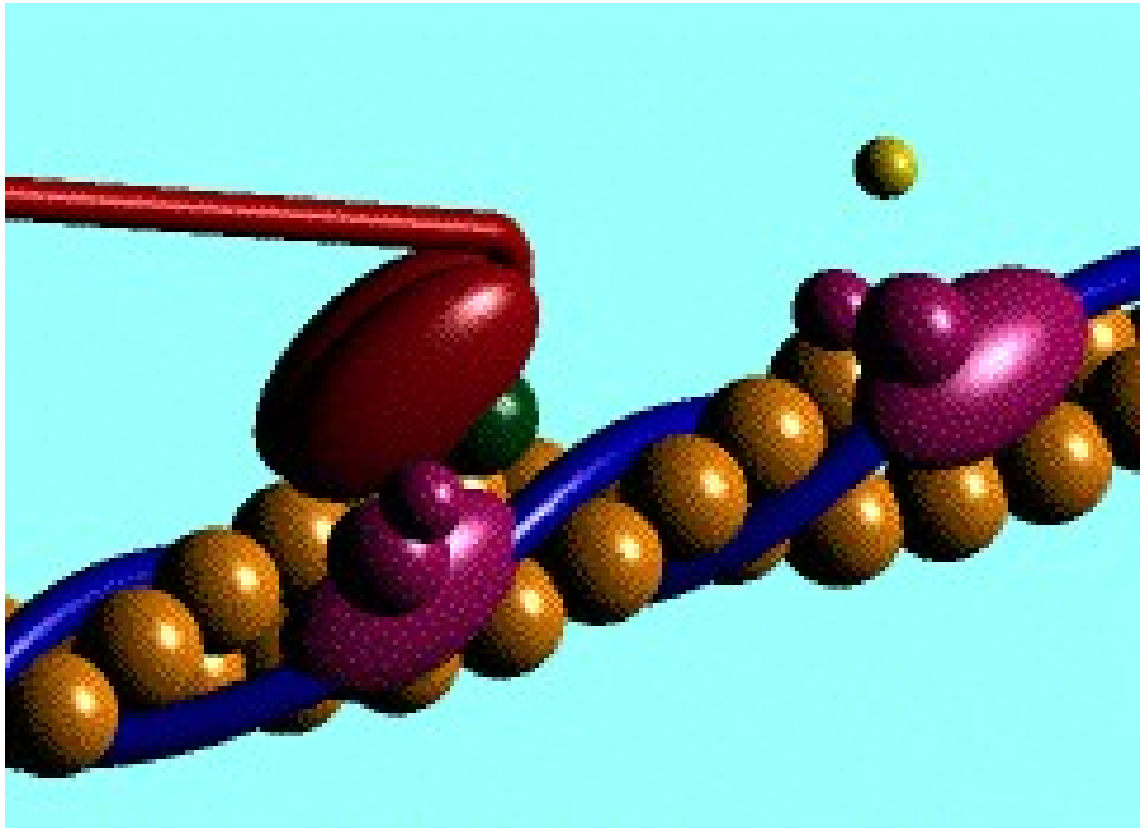
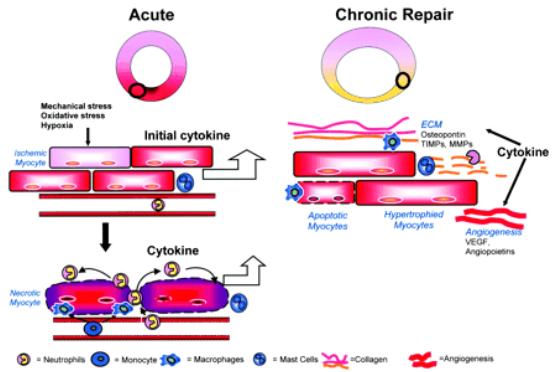
Figure 19-1 Braunwald 2005



Cardiac Damage and Repair



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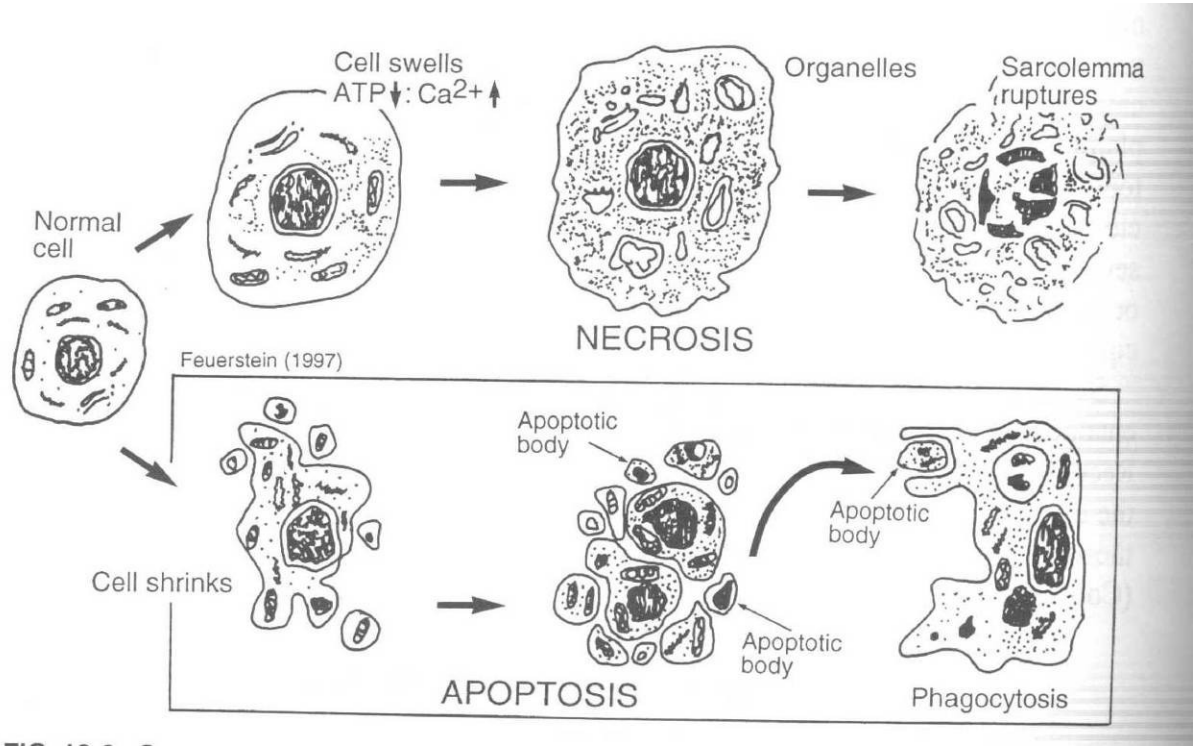
Apoptosis vs. Necrosis



Myocyte Cell Death

- Necrosis
- Apoptosis
- Autophagy

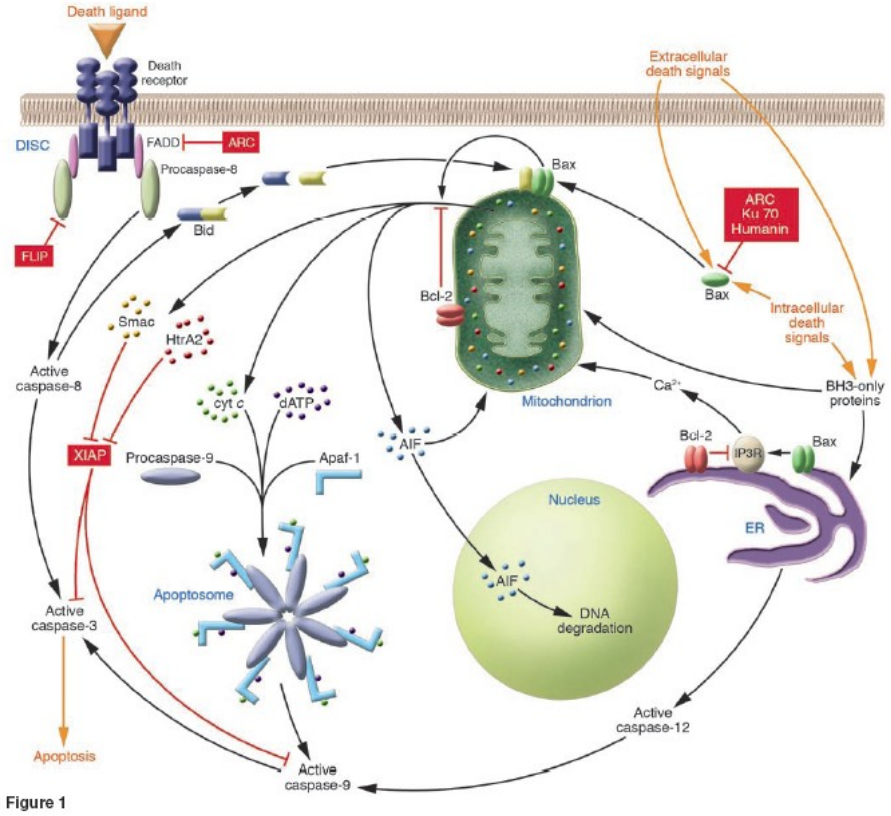
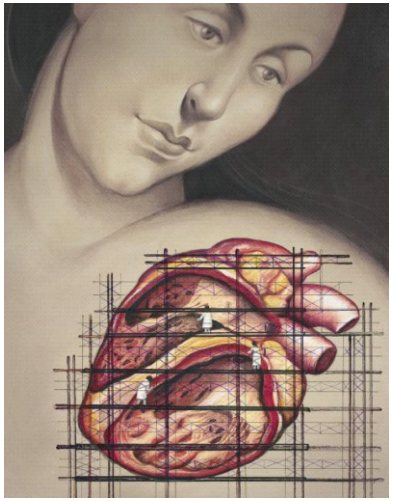


Figure 1

Healing Nomenclature



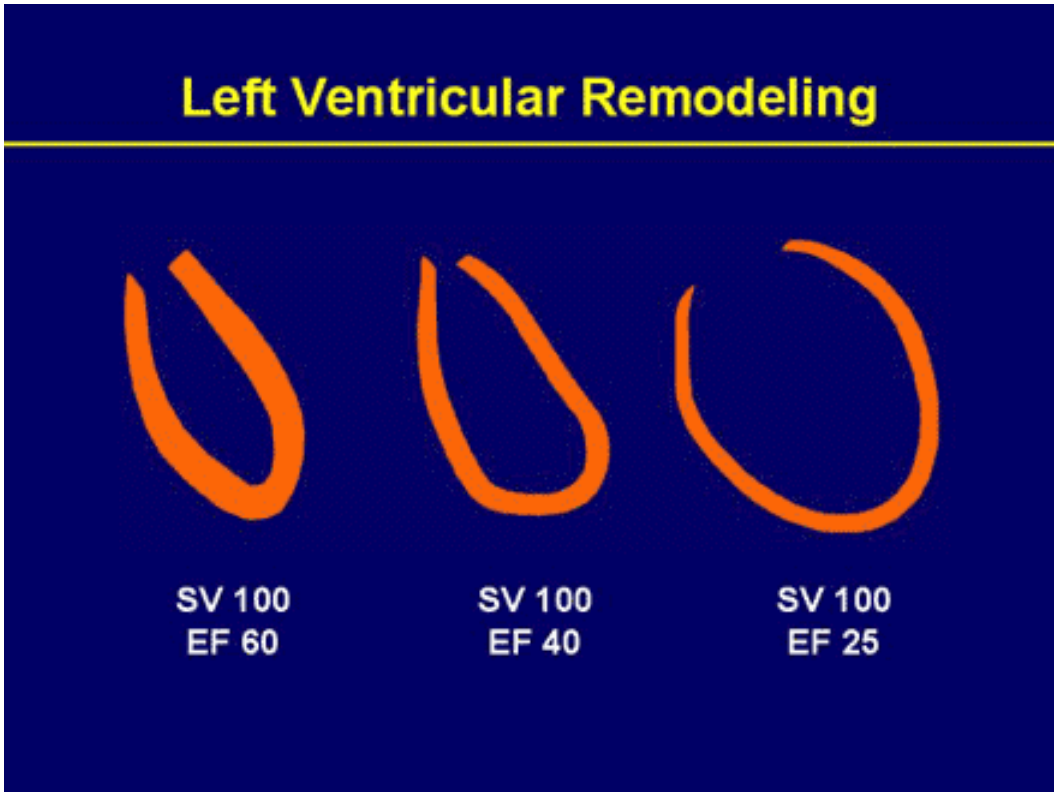
- **Regeneration**

Damaged tissue is replaced from parenchyma.

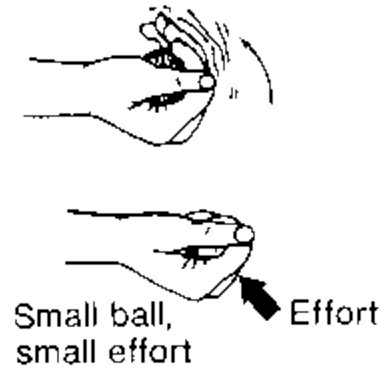
- **Repair**

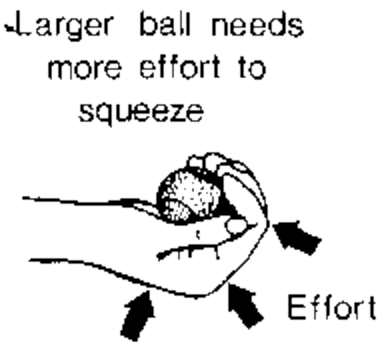
Damaged tissue is replaced by fibrous scar tissue.

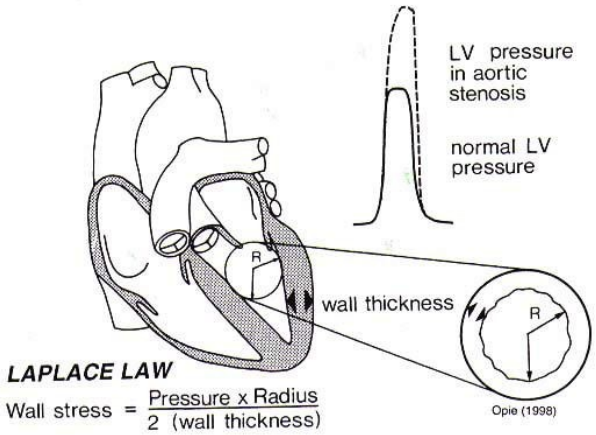
Ventricular remodeling, comprising changes in mass, volume, shape, and composition, constitutes one of the principal mechanisms by which the heart compensates for an increased load


Left Ventricular Remodeling
SV 100
EF 60
SV 100
EF 40
SV 100
EF 25

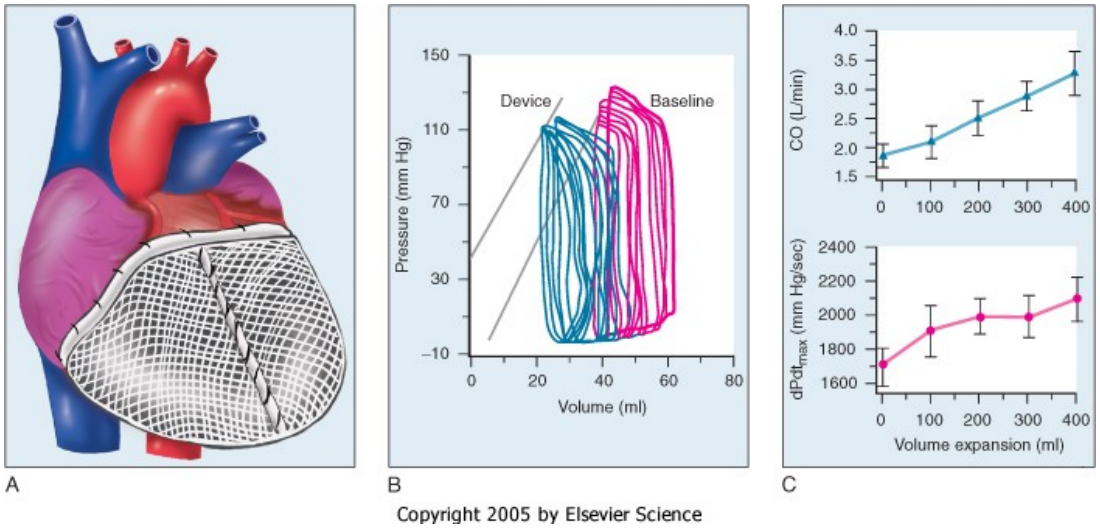
LV Dilatation







Cardiac Support Device



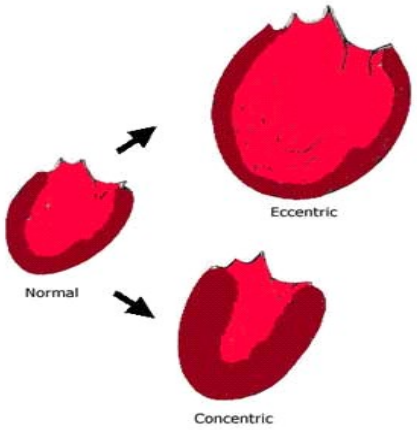


Figure 20-1

TABLE 22–1 Overview of Left Ventricular (LV) Remodeling

Alterations in Myocyte Biology

Excitation contraction coupling
Myosin heavy chain (fetal) gene expression
Beta-adrenergic desensitization
Hypertrophy
Myocytolysis
Cytoskeletal proteins

Myocardial Changes

Myocyte loss
- Necrosis
- Apoptosis
- Autophagy

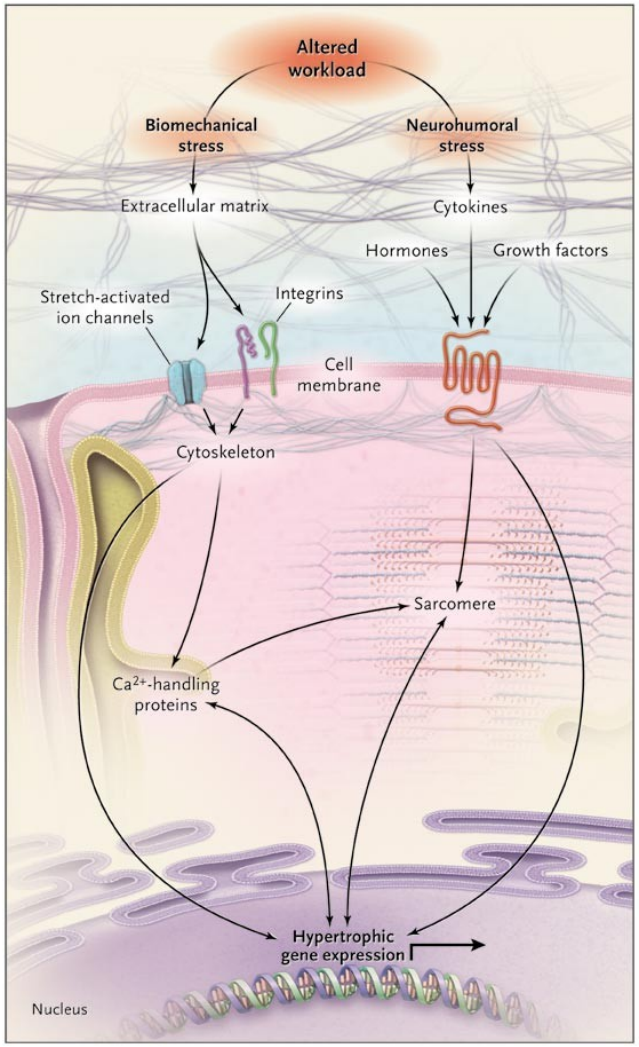
Alterations in extracellular matrix
- Matrix degradation
- Myocardial fibrosis

Alterations in Left Ventricular Chamber Geometry

- LV dilation
- Increased LV sphericity
- LV wall thinning
- Mitral valve incompetence

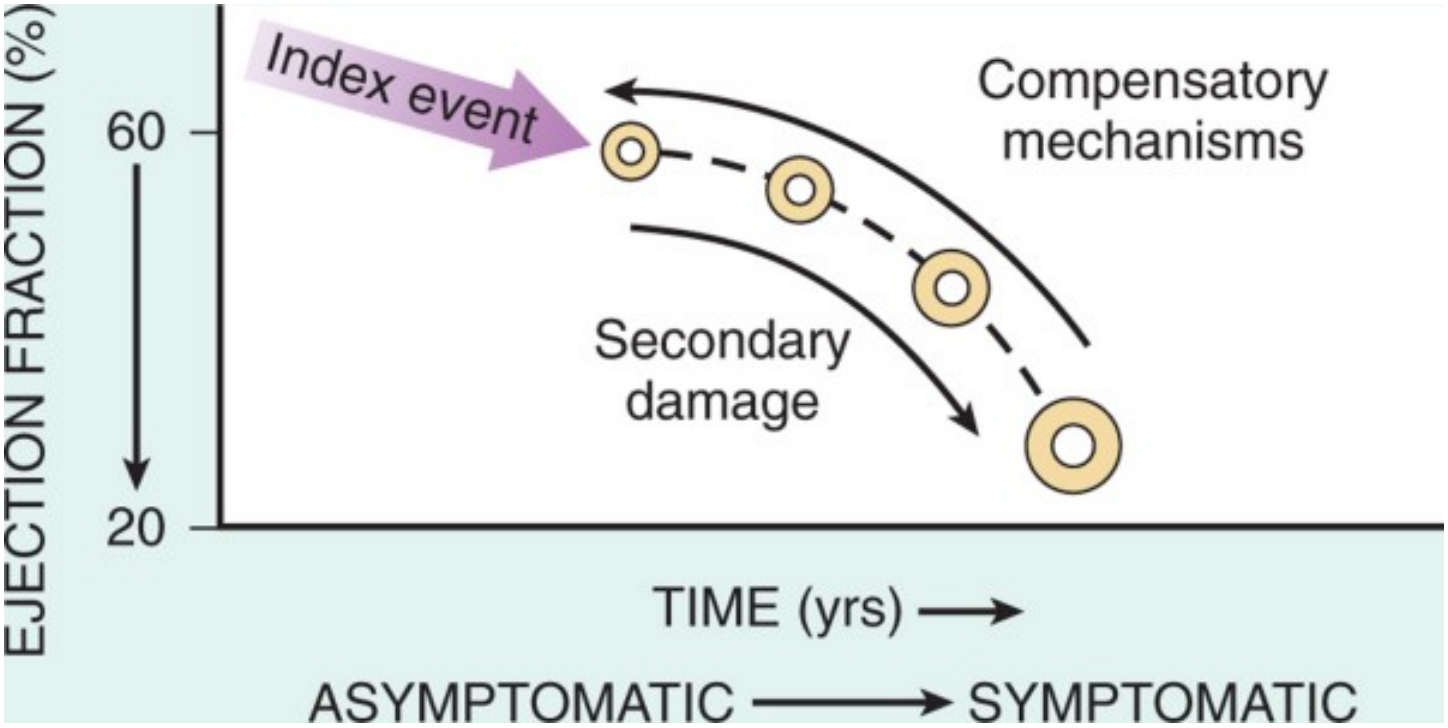
Cellular Events Triggered by Altered Workload.

A complex interplay of biomechanical and neurohumoral stress responses culminates in hypertrophic gene regulation and cell growth



Hill & Olson NEJM 2008

Pathogenesis of heart failure



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Apoptosis
Autophagy
Alterations in extracellular matrix
Matrix degradation
Myocardial fibrosis
Alterations in Left Ventricular Chamber Geometry
LV dilation
Increased LV sphericity
LV wall thinning
Mitral valve incompetence

Overview of the pathophysiology of myocardial remodeling

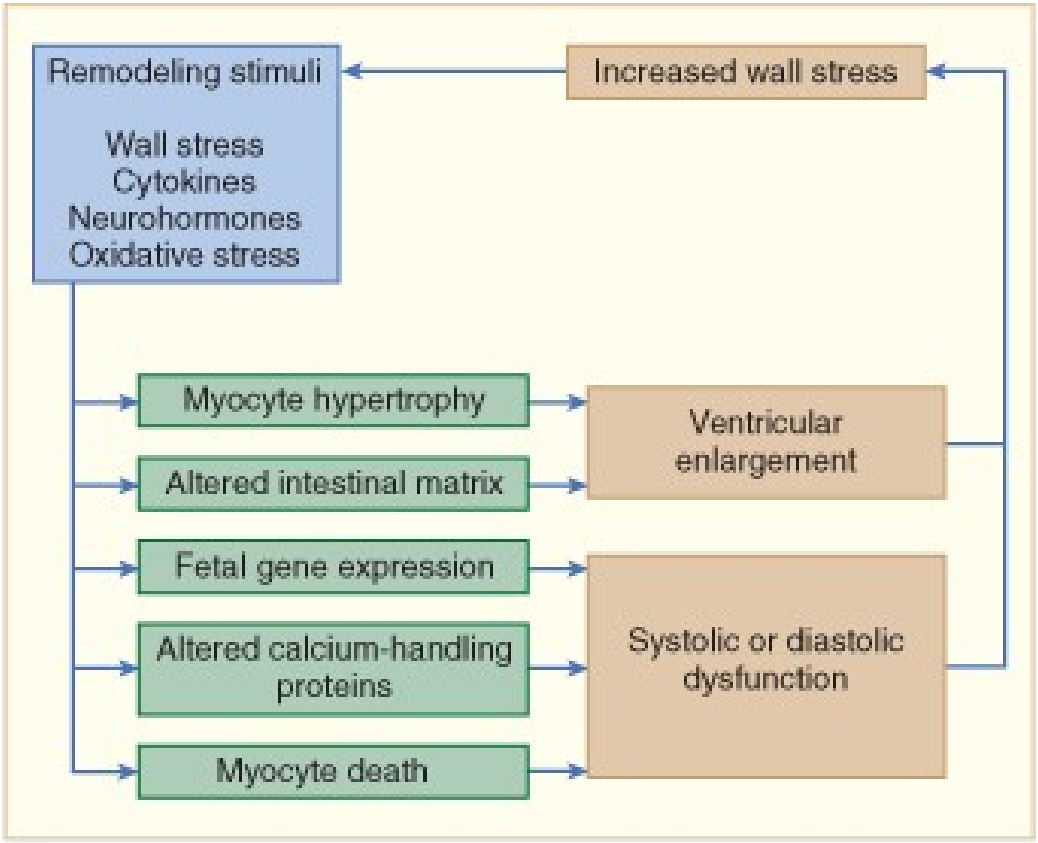
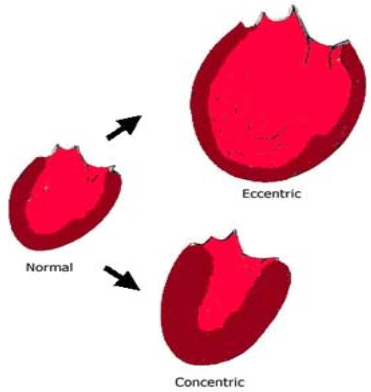
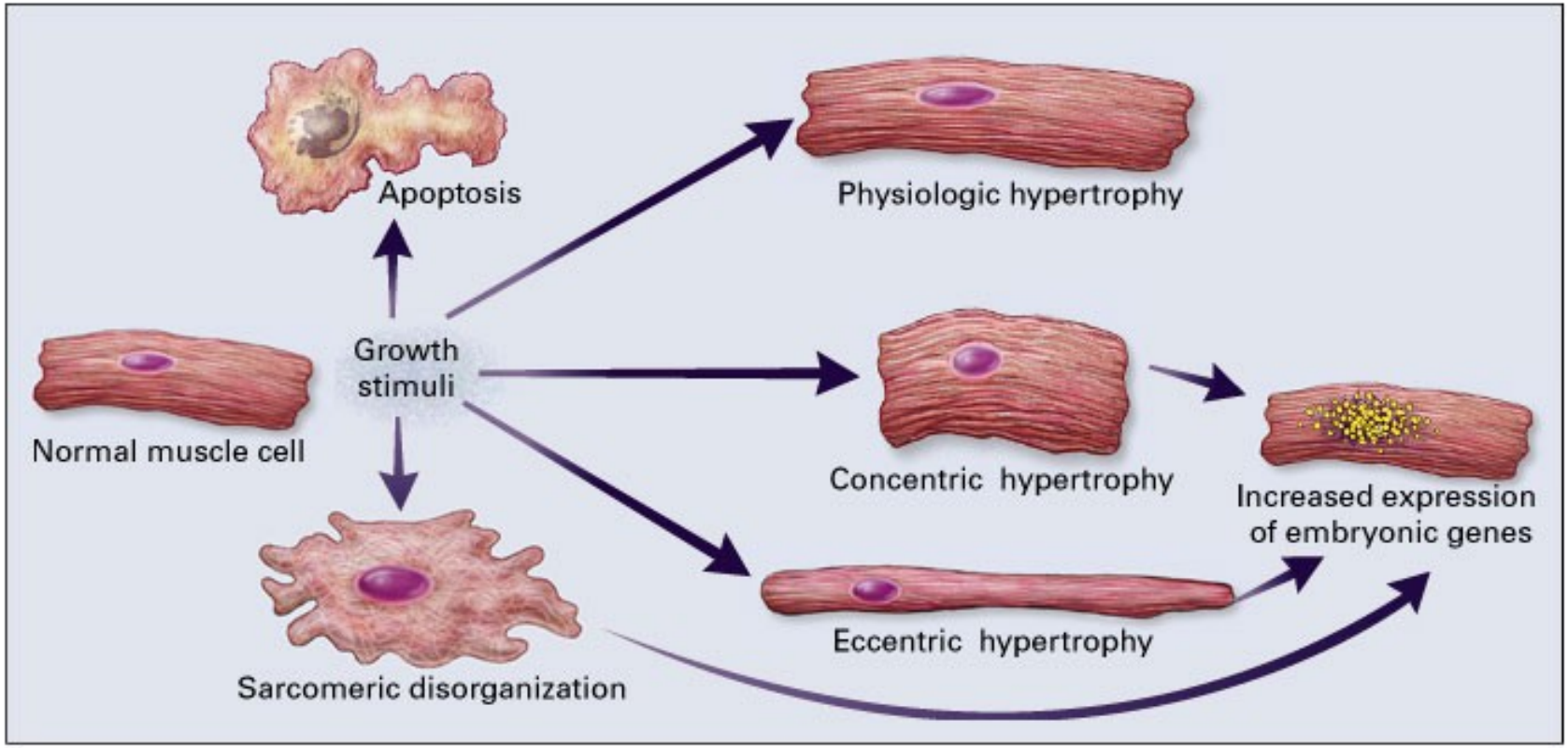


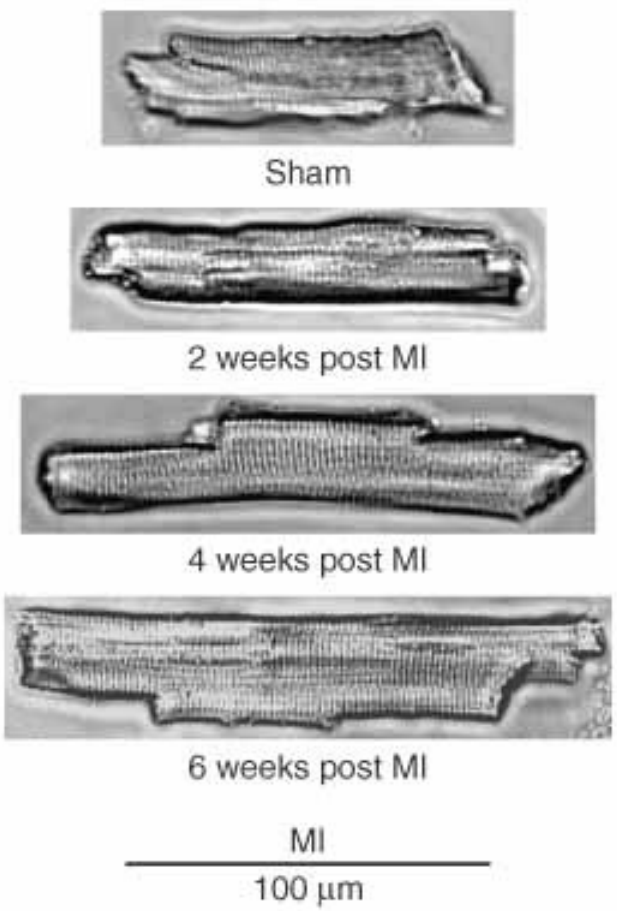
Figure 21-10

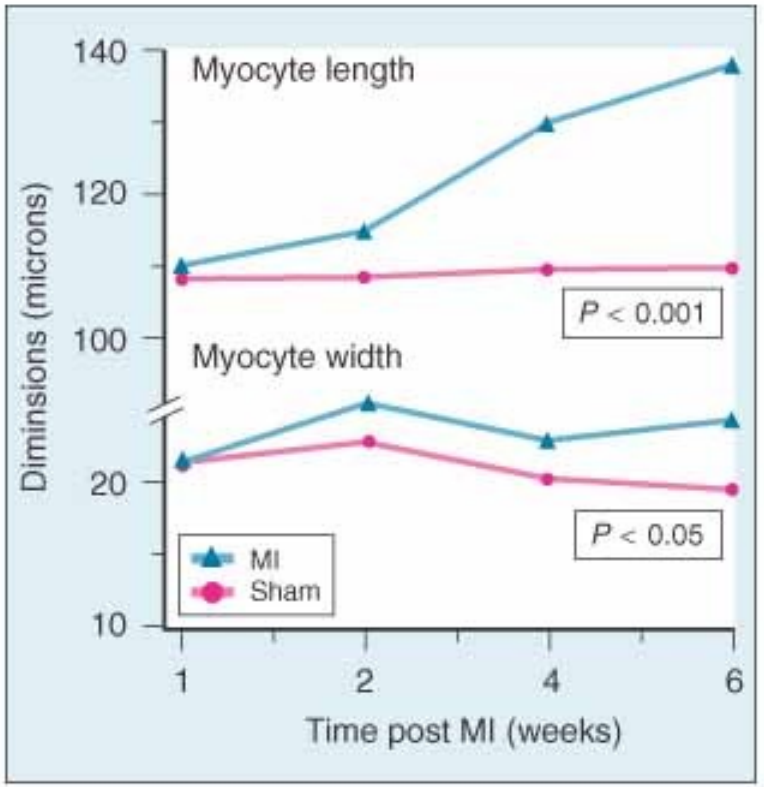
Cellular Hypertrophy





Cardiac myocyte remodeling
Increased myocyte length and width





cardiac hypertrophy

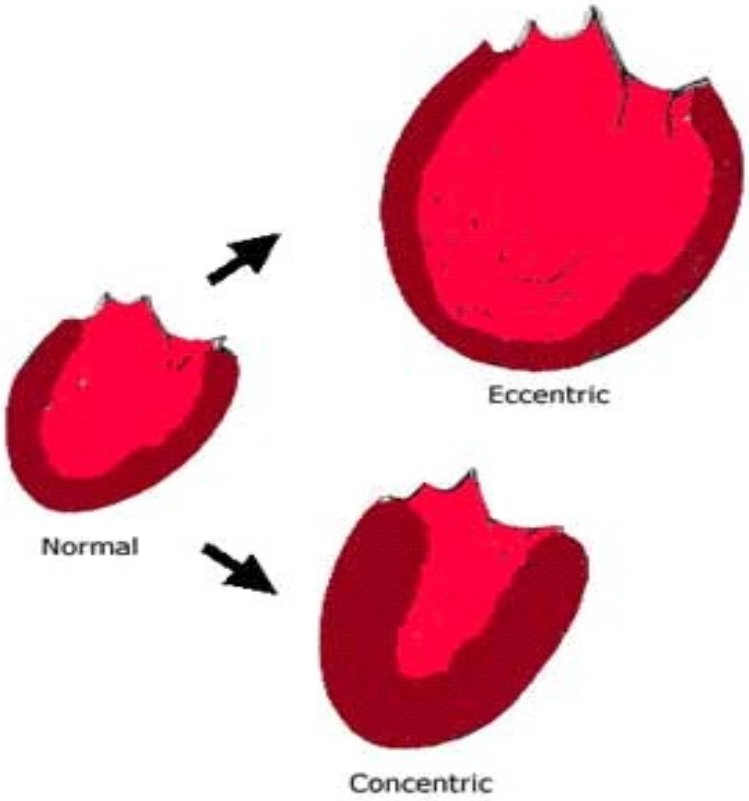
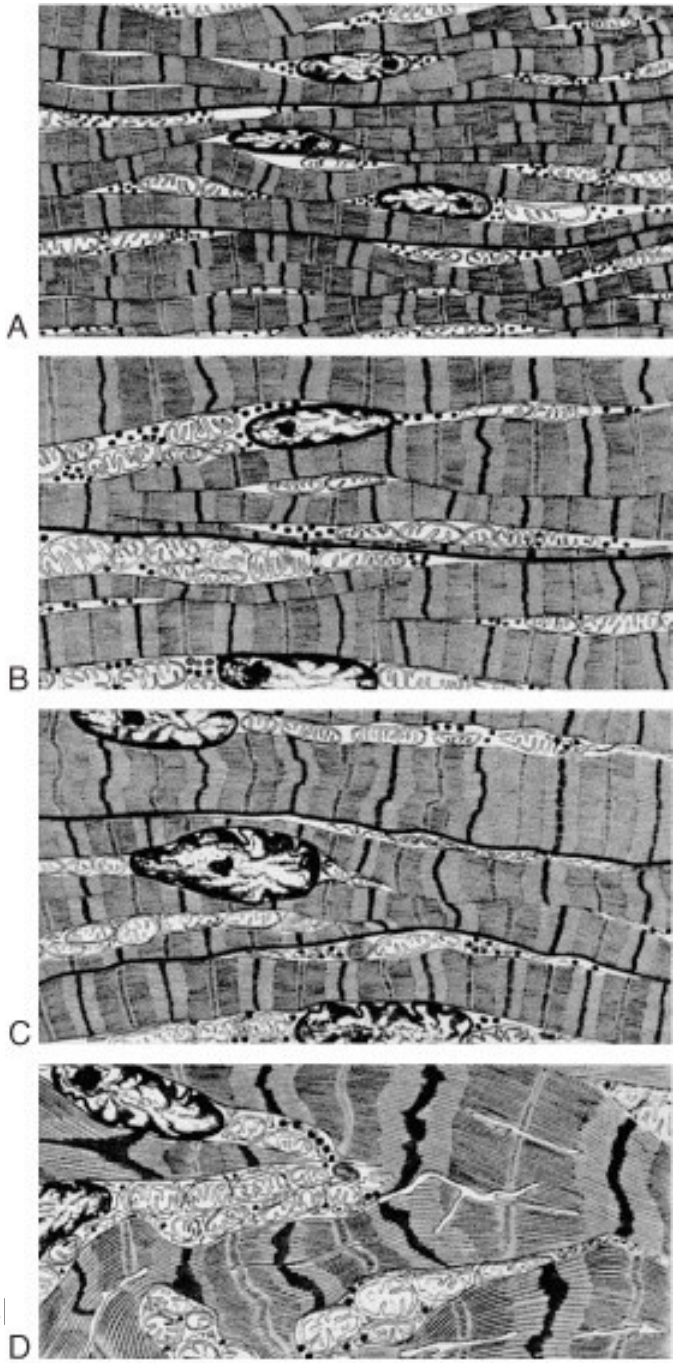


Figure 21-8



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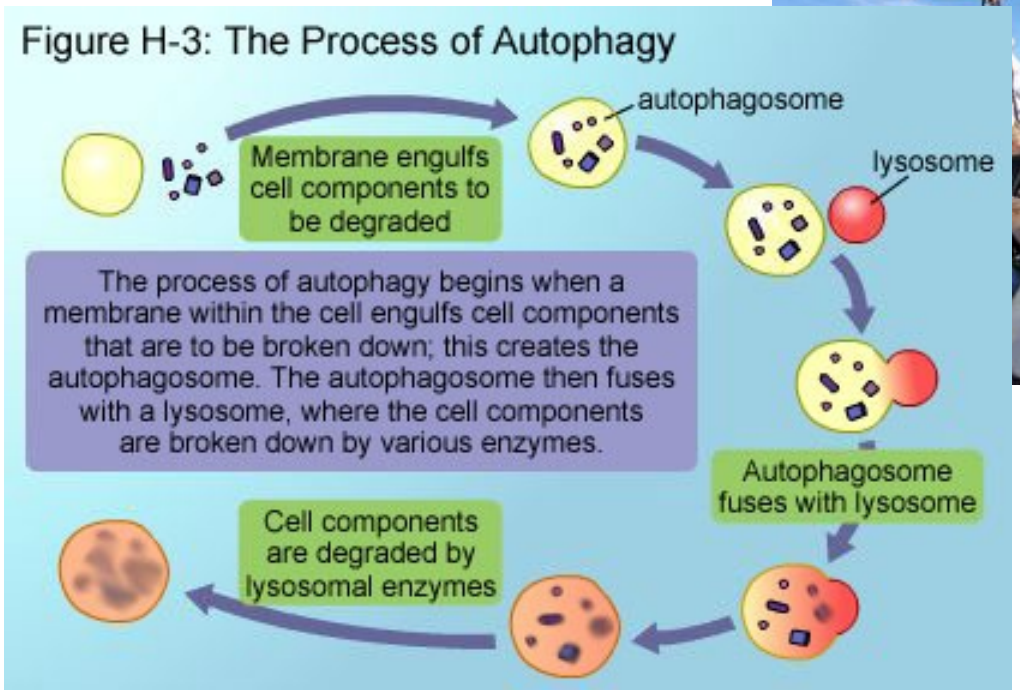
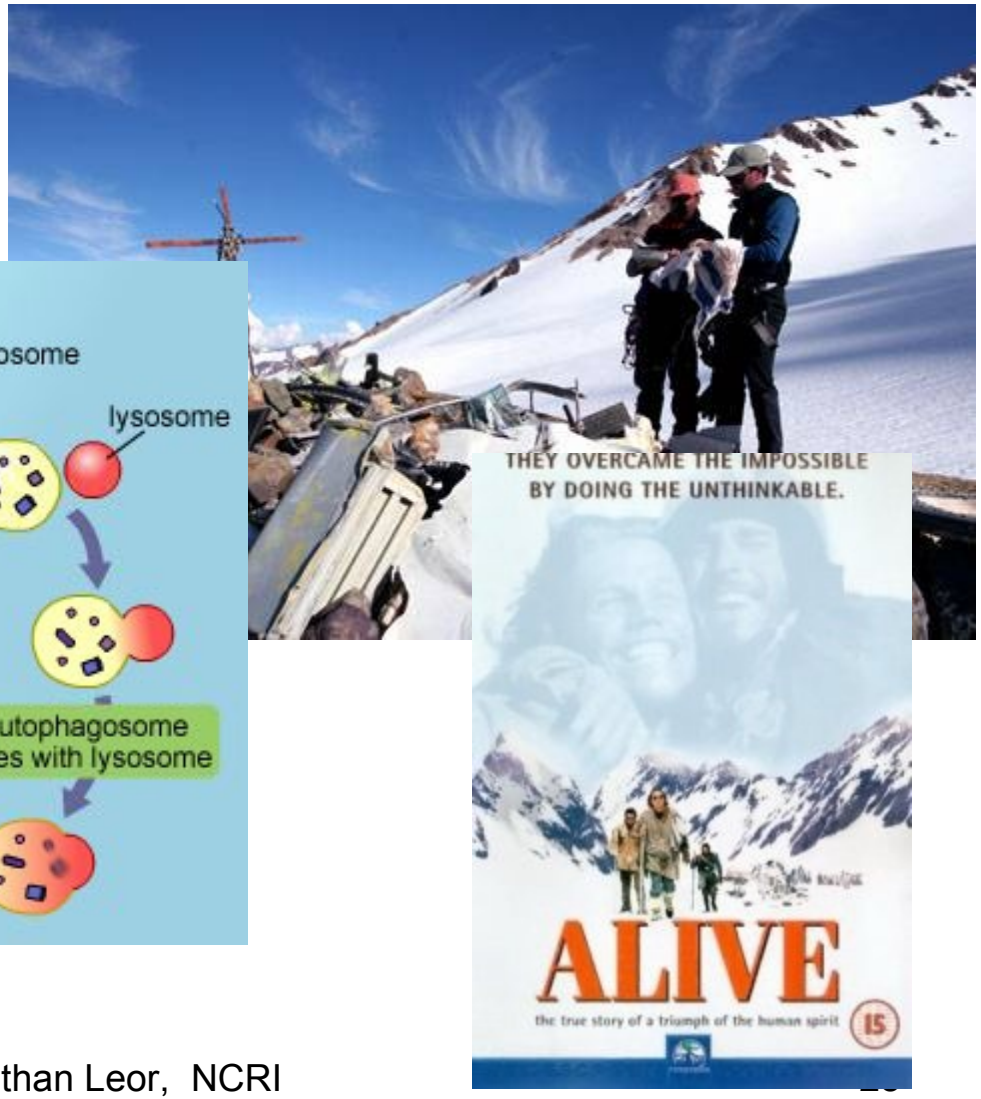
Autophagy





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Small RNAs in a big heart

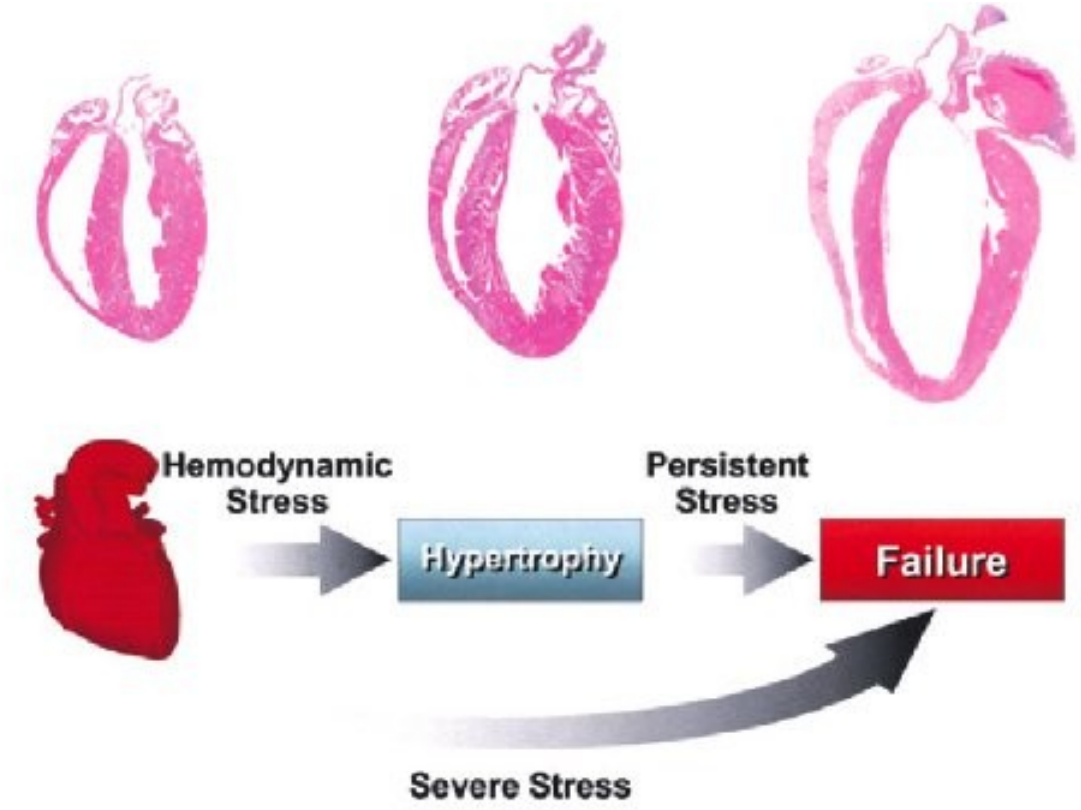
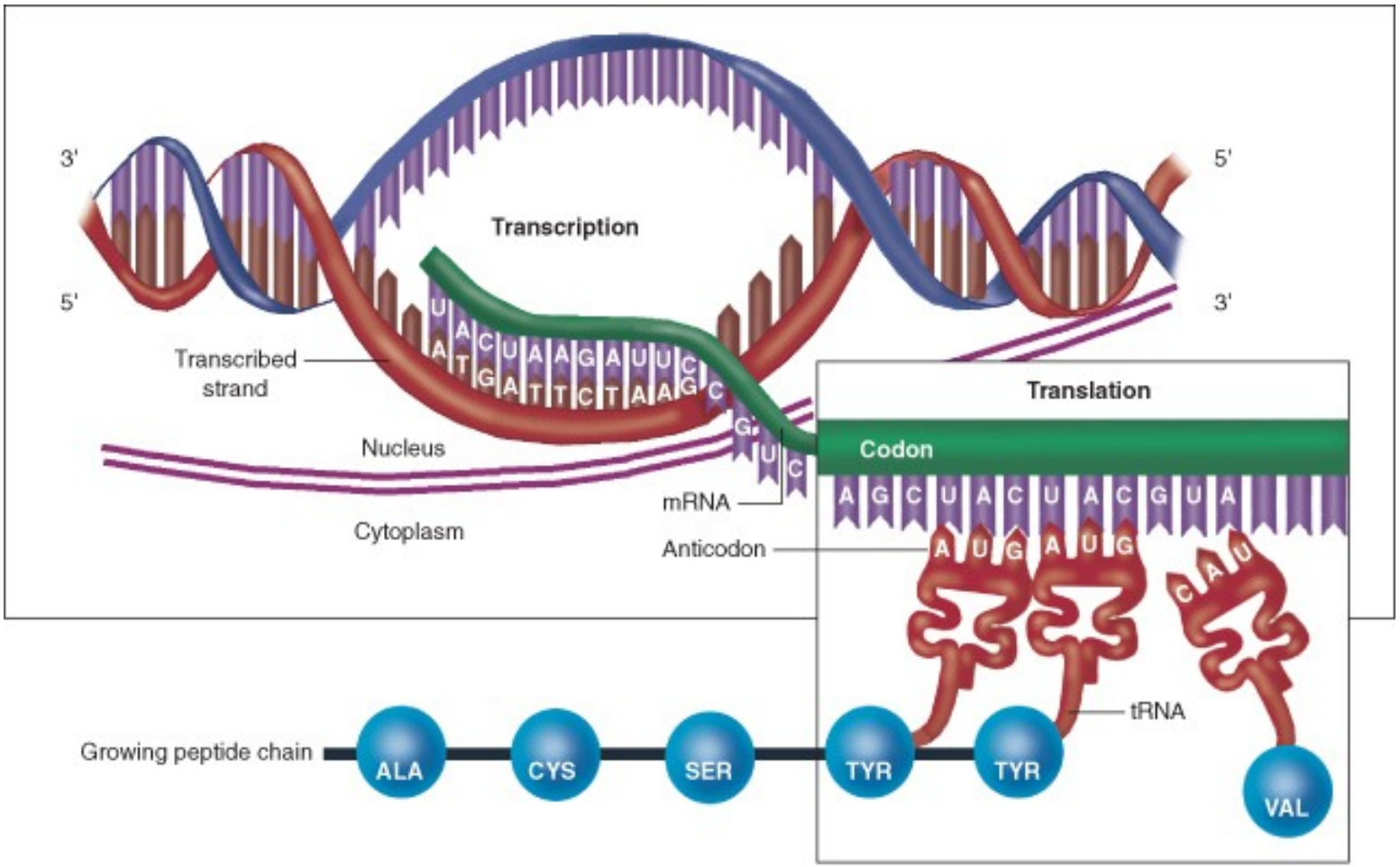
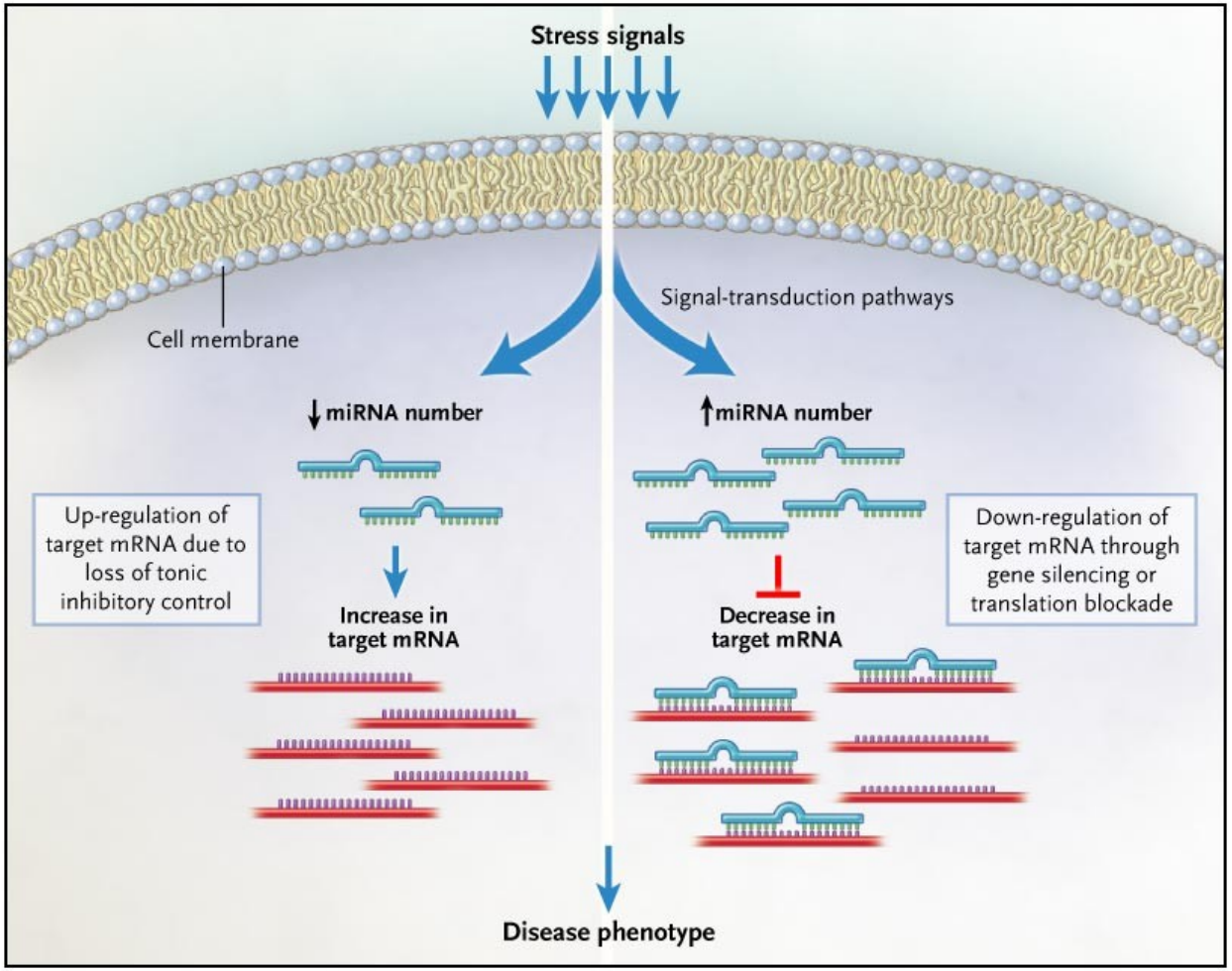


Figure 69-6 The flow of genetic information. Transcription in the nucleus creates a complementary ribonucleic acid copy from one of the DNA strands in the double helix. mRNA is transported into the cytoplasm, where it is translated into protein

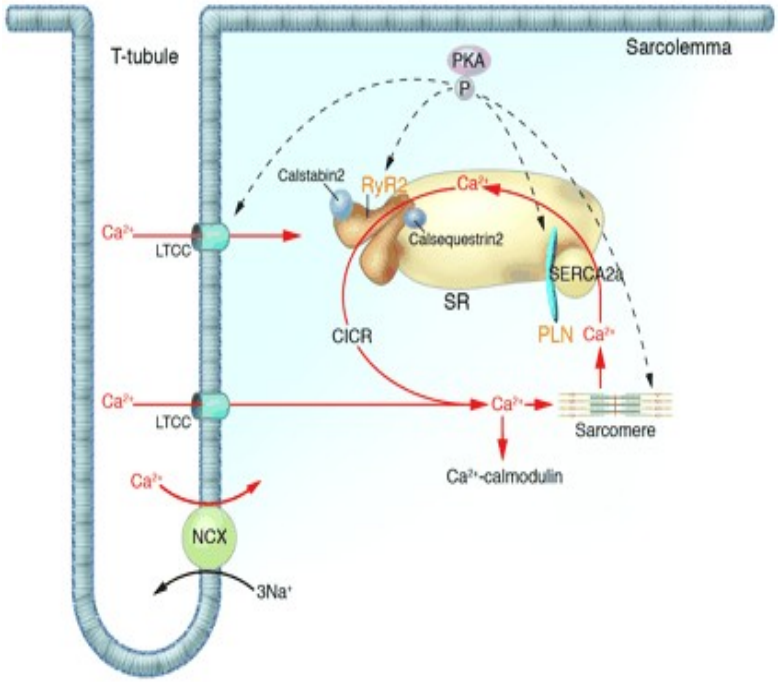


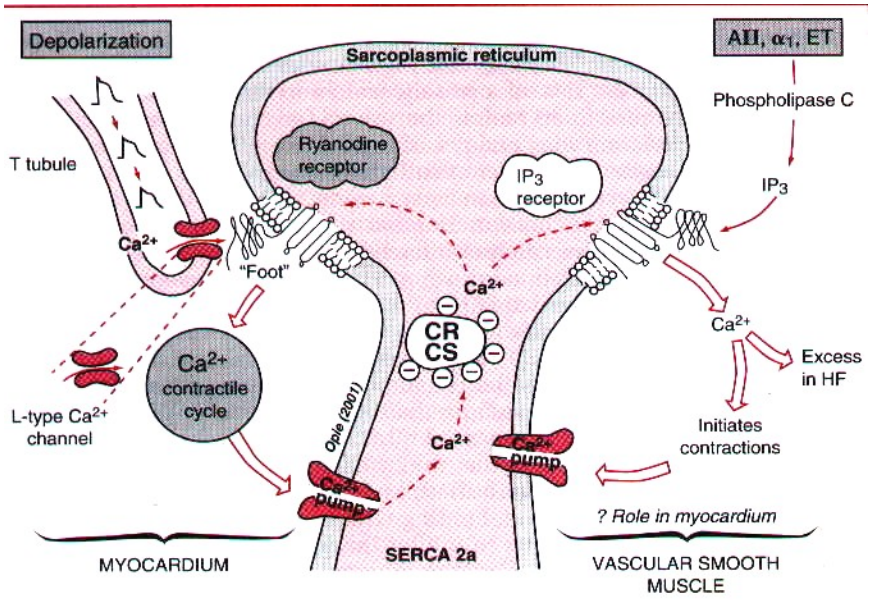
MicroRNAs as Mediators



Mann D. N Engl J Med 2007;356:2644-2645

Human mutations affecting Ca2+ cycling proteins





J. Clin. Invest. **115**:518-526 (2005)

Braunwald p 453

Calcium Hemostasis in Failing Human Myocardium

- **<u>Intracellular Calcium levels</u>**
- Basal (diastolic) ↑
- Peak (systolic) ↓
- Rate of fall with diastole ↓

From Braunwald pp

Alterations in beta-adrenergic pathways in the failing heart

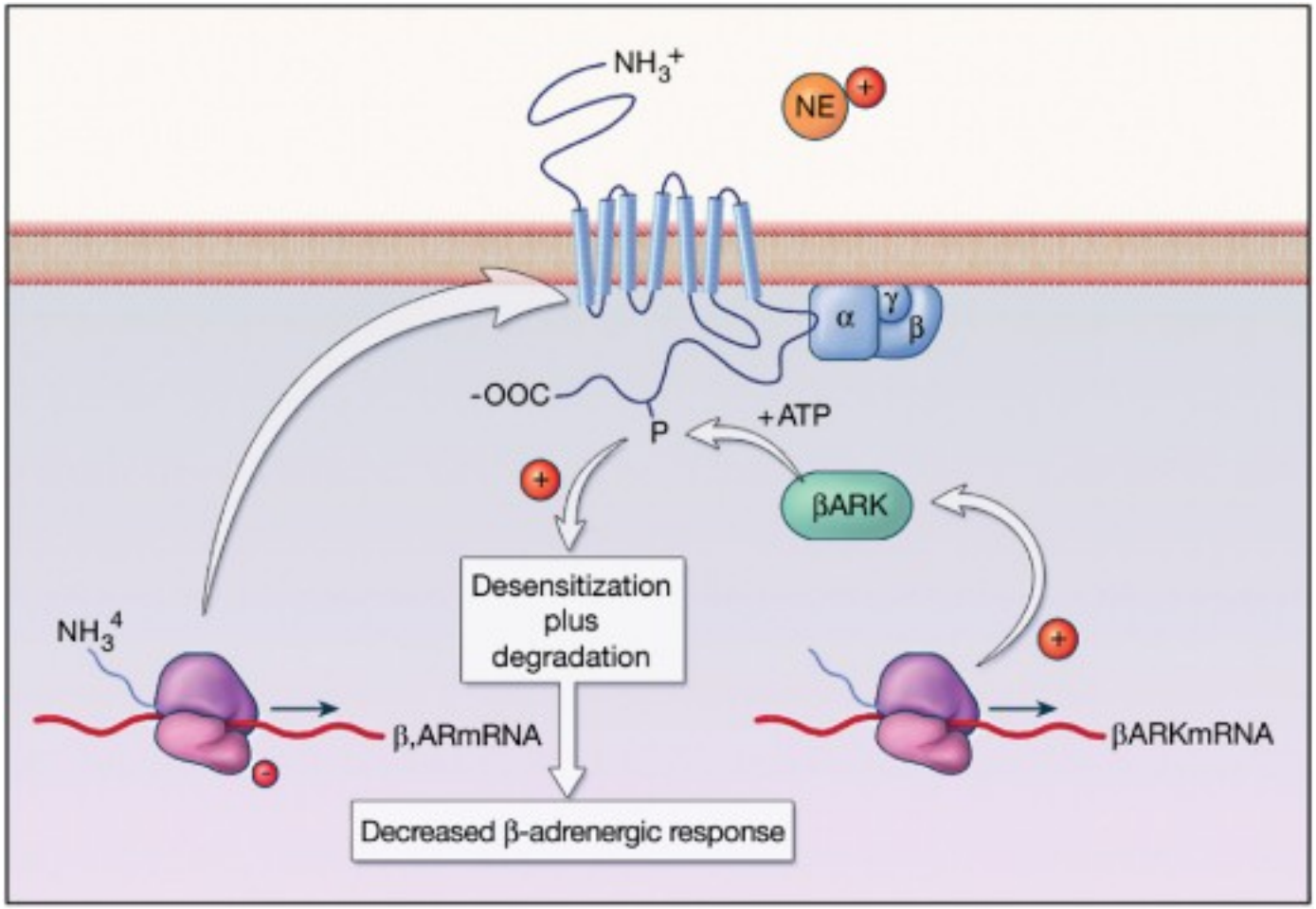


TABLE 22–4	Effects of Inflammatory Mediators on Left Ventricular Remodeling
Alterations in the Biology of the Myocyte	
Myocyte hypertrophy	
Fetal gene expression	
Negative inotropic effects	
Increased oxidative stress	
Alterations in the Biology of the Nonmyocytes	
Conversion of fibroblasts to myofibroblasts	
Upregulation of AT_1 receptors on fibroblasts	
Increased matrix metalloproteinase secretion by fibroblasts	
Alterations in the extracellular matrix	
Degradation of the matrix	
Myocardial fibrosis	
Progressive Myocyte Loss	
Necrosis	
Apoptosis	

TABLE 22–4 Effects of Infl ammatory Mediators on Left Ventricular Remodeling.

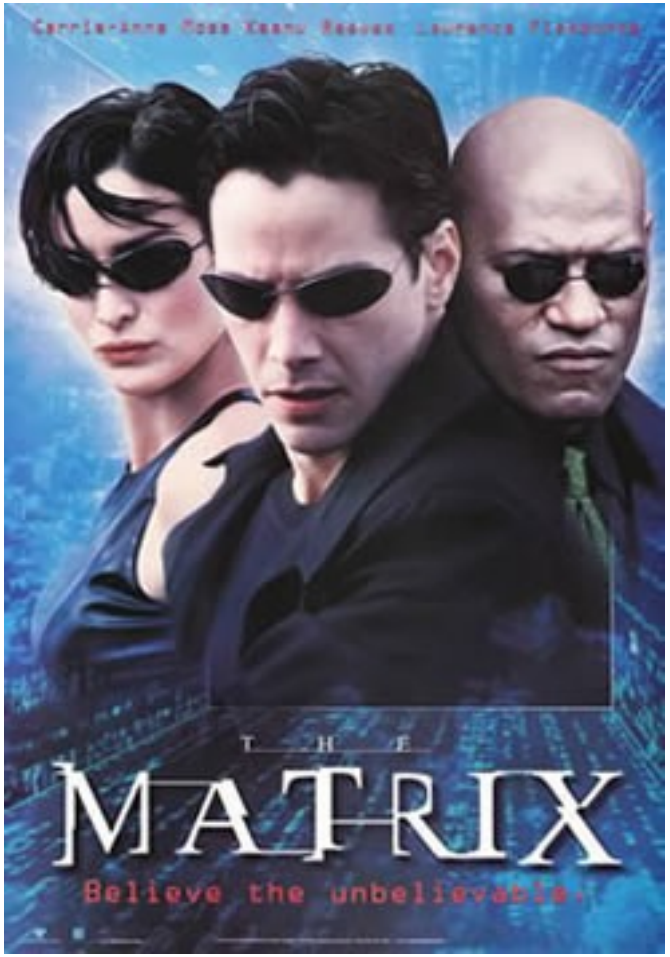
Braunwald Table 29-5

TABLE 29-5 -- Potential Therapeutic Targets for Gene Therapy in Heart Failure

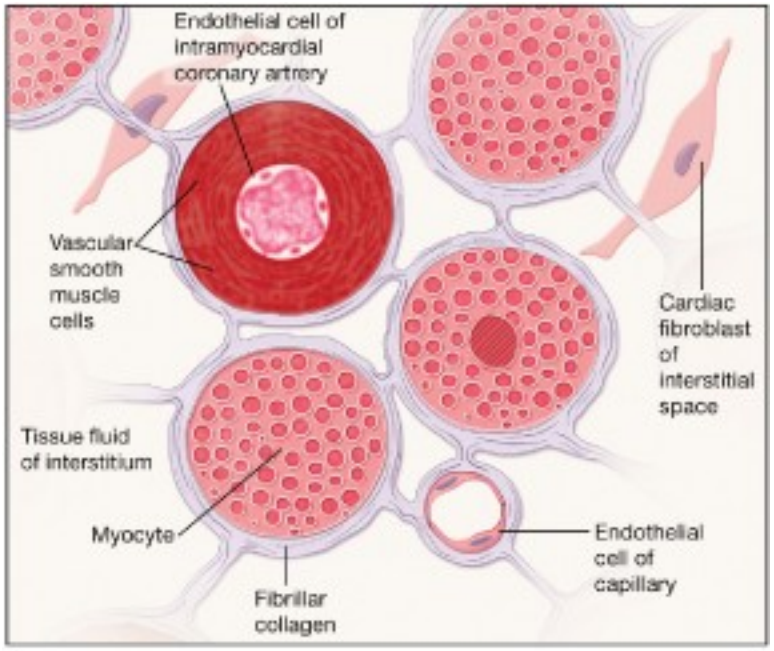
Target	Function
Beta-adrenergic receptor kinase inhibitor (βARKct)	Inhibits phosphorylation of β-adrenergic receptor thus preventing its desensitization
Adenylyl cyclase (AC)	Synthesizes cAMP to activate PKA, which then phosphorylates substrates to regulate calcium handling
Sarcoplasmic reticulum Ca^{2+} ATPase (SERCA2)	Responsible for the reuptake of calcium from cytoplasm into the SR lumen. Critical determinant of both relaxation and contractility via calcium sequestration into SR and via controlling SR calcium loading, respectively
Phospholamban (PLN)	Inhibits SERCA2, inactivated by phosphorylation by PKA and CaMKII
Parvalbumin (Parv)	Rapidly removes calcium in myofilaments, naturally abundant in skeletal muscle (not cardiac); results in enhanced relaxation
S100 protein	A calcium binding protein, a positive inotropic regulator of cardiac function that

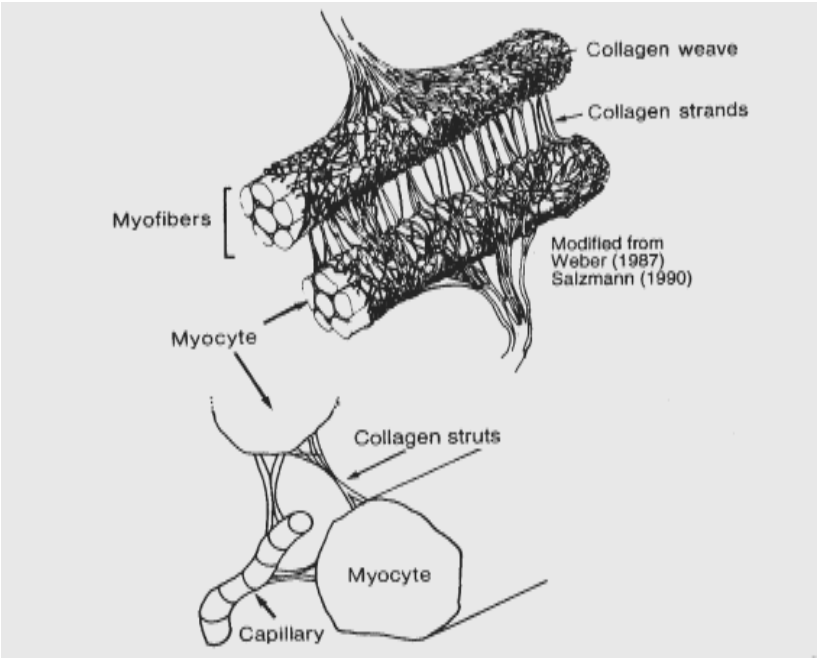
Braunwald Table 29-6

Effect of Gene Polymorphisms on the Pharmacological Treatment of Heart Failure

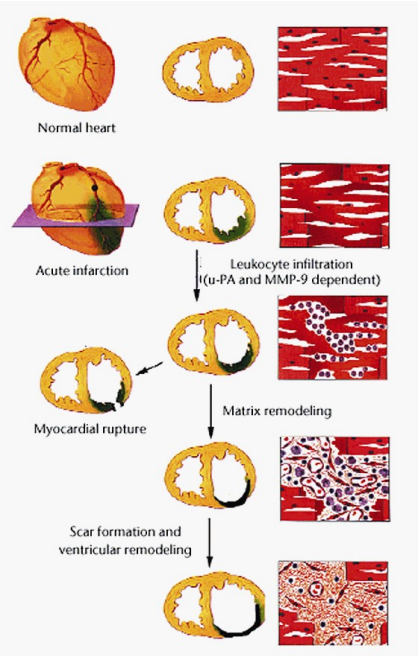

THE
MATRIX
Believe the unbelievable.

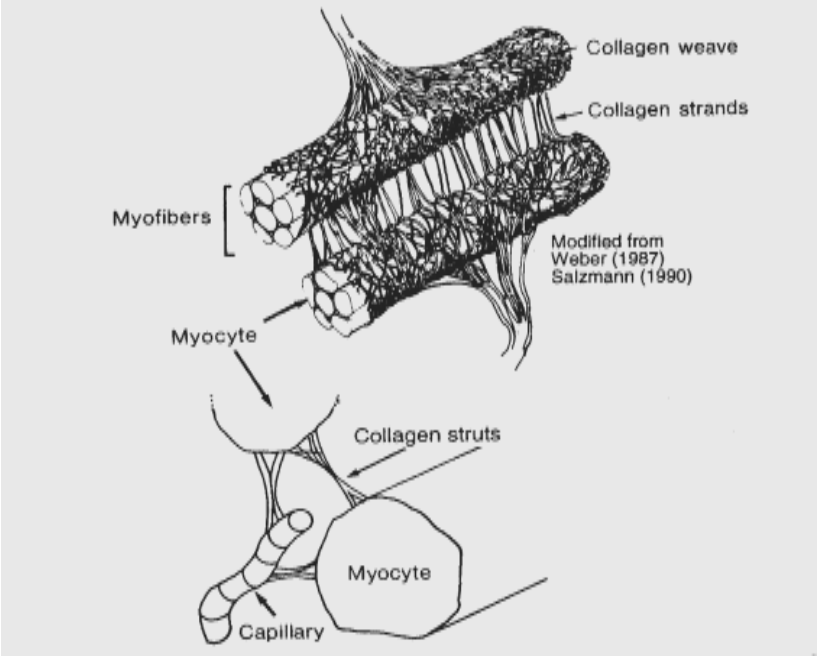
Extra Cellular Matrix





MMP activity site





- Extra cellular matrix degradation causes
  - cardiomyocyte realignment
  - wall thinning
  - LV dilatation
  - heart failure

The regulation of extracellular matrix degradation

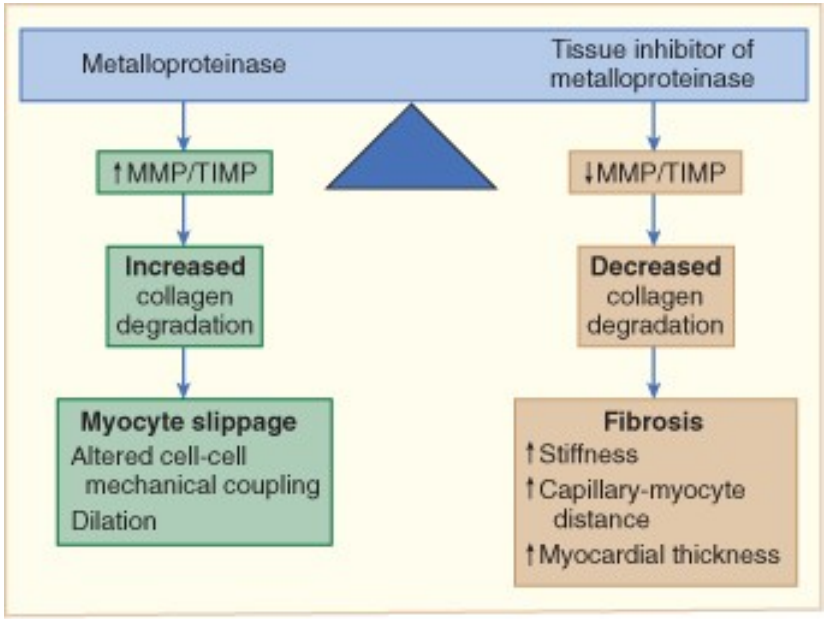


Figure 21-18

Factors responsible for diastolic dysfunction

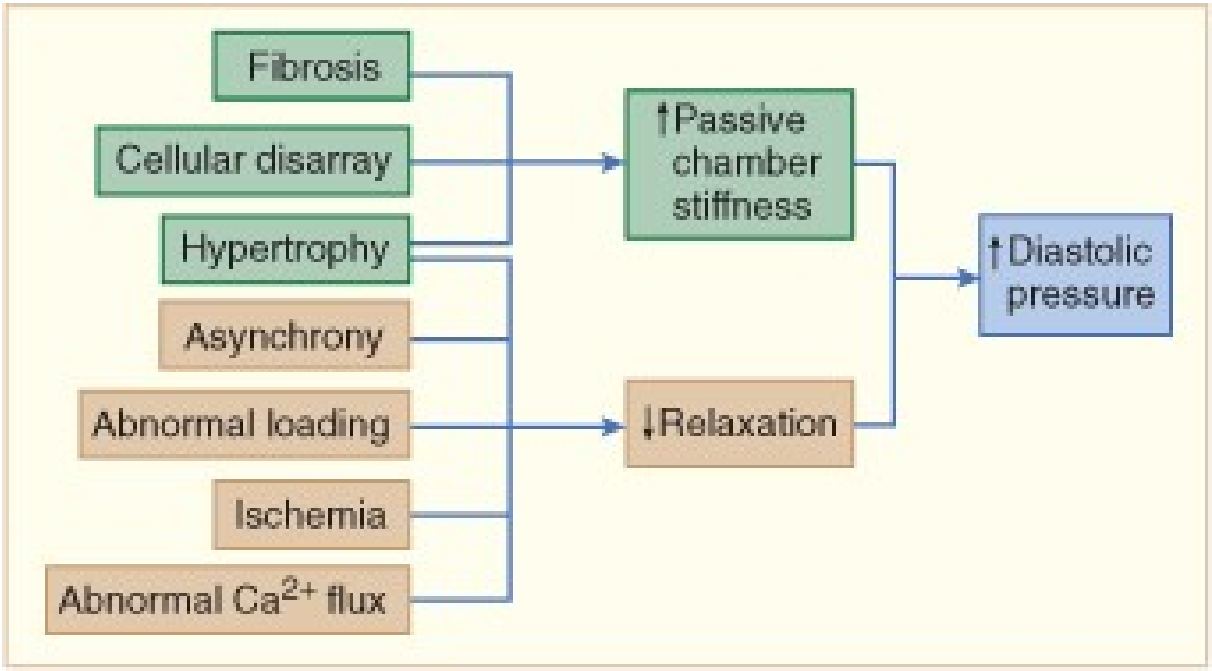
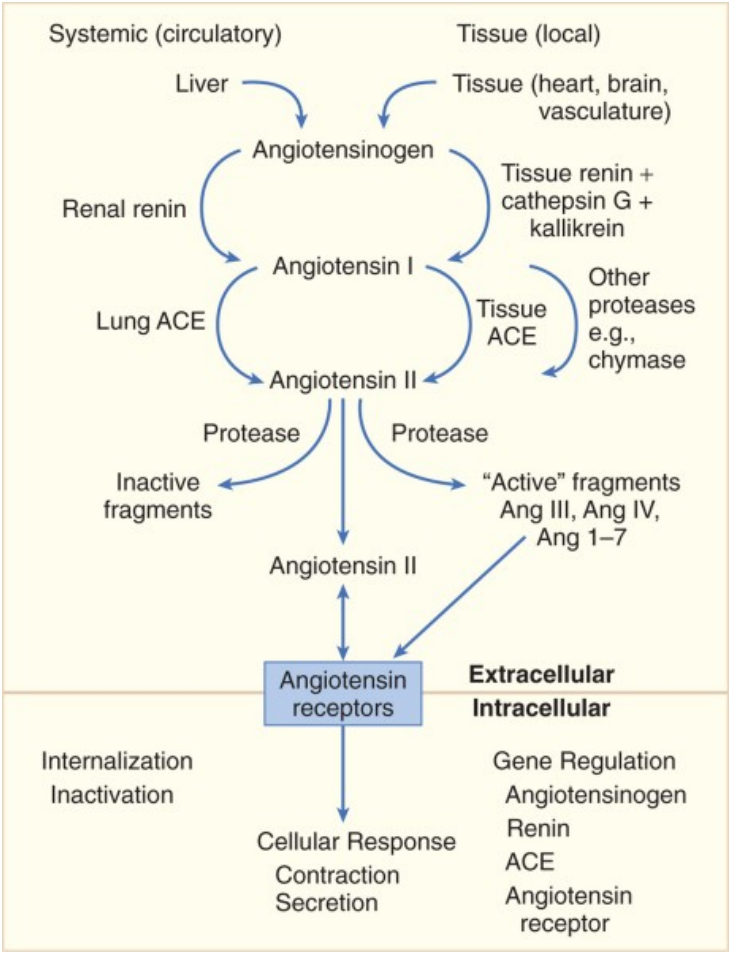


Figure 21-21

FIGURE 22-4 The systemic and tissue components of the renin-angiotensin system



Angiotensin II and Myocardium

1. Myocyte hypertrophy
2. Myocyte apoptosis
3. Fibrosis
4. Matrix remodeling (collagen deposition)
5. Inflammation
6. Oxidative stress

Summary
LV Remodeling
at the molecular and cellular level

1. Myocyte growth or hypertrophy.
2. Changes in myocyte phenotype with reexpression of fetal gene programs.
3. Alterations in proteins involved in excitation-contraction coupling and contraction.
4. Myocyte death due to necrosis and apoptosis
5. Changes in the extracellular matrix.
6. Abnormalities in energetics.

Processes Occurring in Ventricular Remodeling (2)

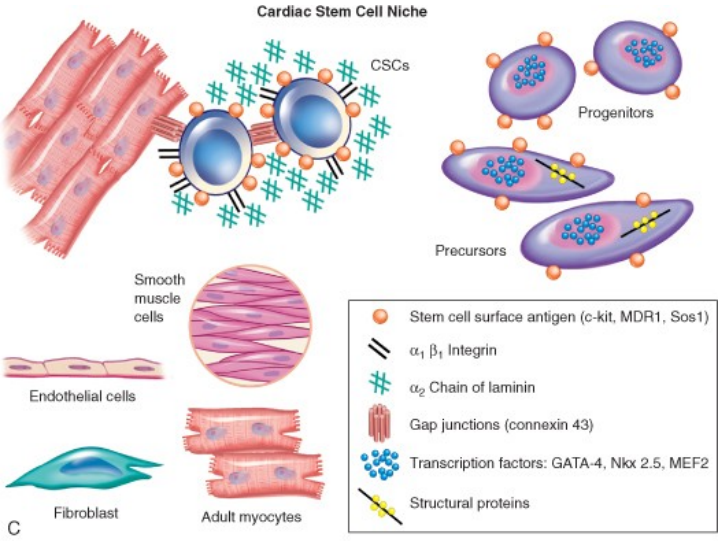
1. Continued expansion of infarct zone
2. Dilation and reshaping of the left ventricle
3. Myocyte hypertrophy
4. Ongoing myocyte loss
5. Excessive accumulation of collagen in the cardiac interstitium

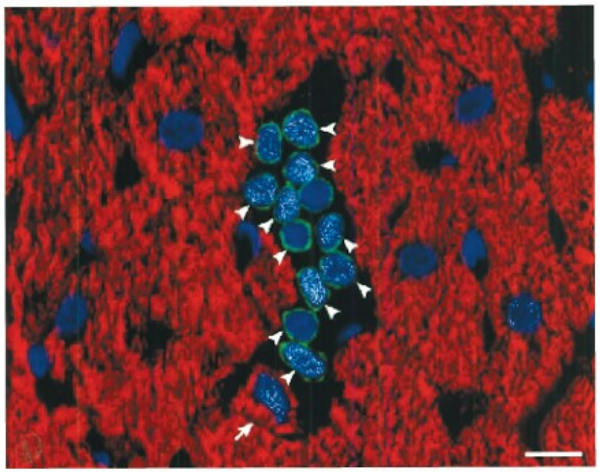
Table 22-5

TABLE 22-5 -- Cellular and Molecular Determinants of Myocardial Recovery

	ACE Inhibitor	Beta Blocker	LVAD	CSD
Myocyte Defects				
Hypertrophy	Decreased	Decreased	Decreased	Decreased
Myocytolysis	ND	Decreased	Decreased	ND
E-C coupling	Increased	Increased	Increased	Increased
Fetal gene expression	Decreased	Decreased	Decreased	Decreased
Beta-adrenergic desensitization	Decreased	Decreased	Decreased	Decreased
Cytoskeletal proteins	ND	ND	Increased	ND
Myocyte contractility	ND	Increased	Increased	Increased
Myocardial Defects				
Myocyte necrosis	Decreased	Decreased	Decreased	ND
Myocyte apoptosis	Decreased	Decreased	Decreased	Decreased
MMP activation	Decreased	Decreased	Decreased	Decreased
Fibrosis	Decreased	Decreased	Decreased	Decreased
LV Dilation	Stabilized	Decreased	Decreased	Decreased

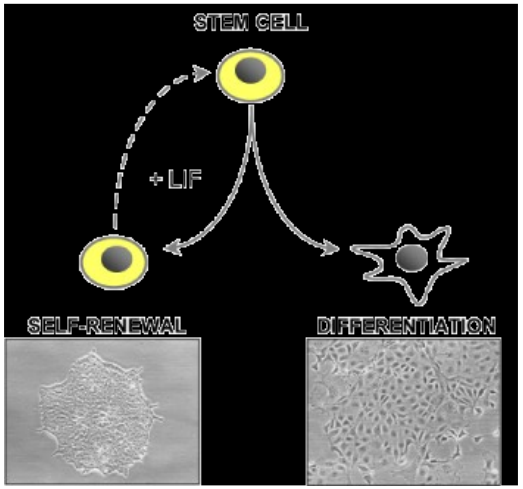
Myocardial regeneration and repair

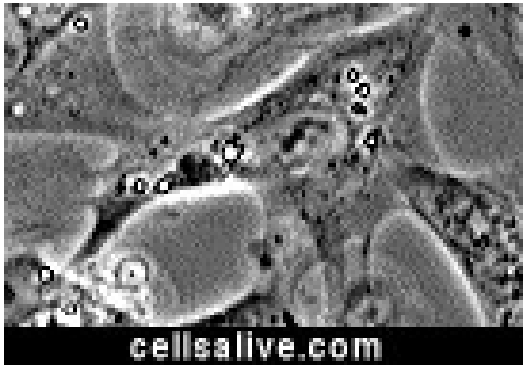




Stem Cell

- Self renewal
- Give rise to specialized cells.





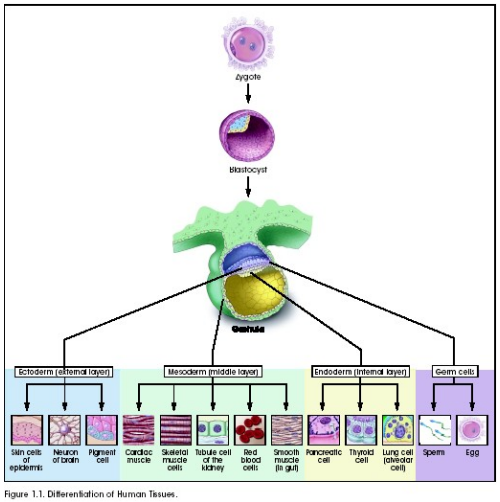
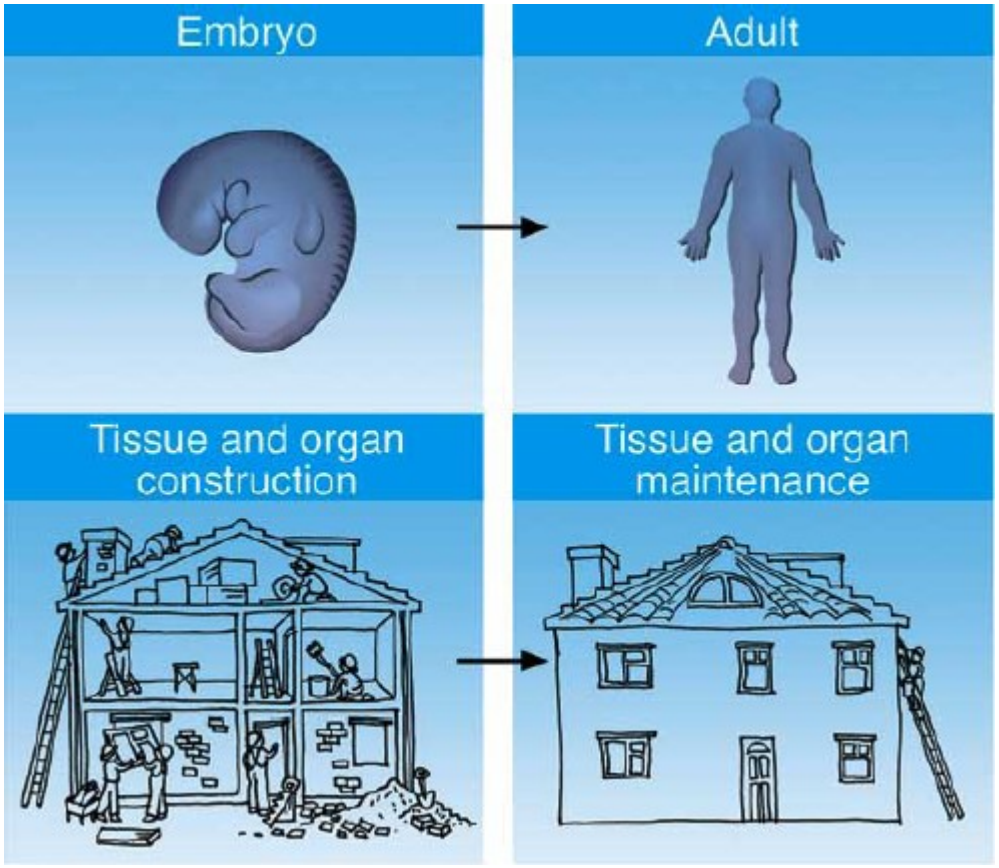
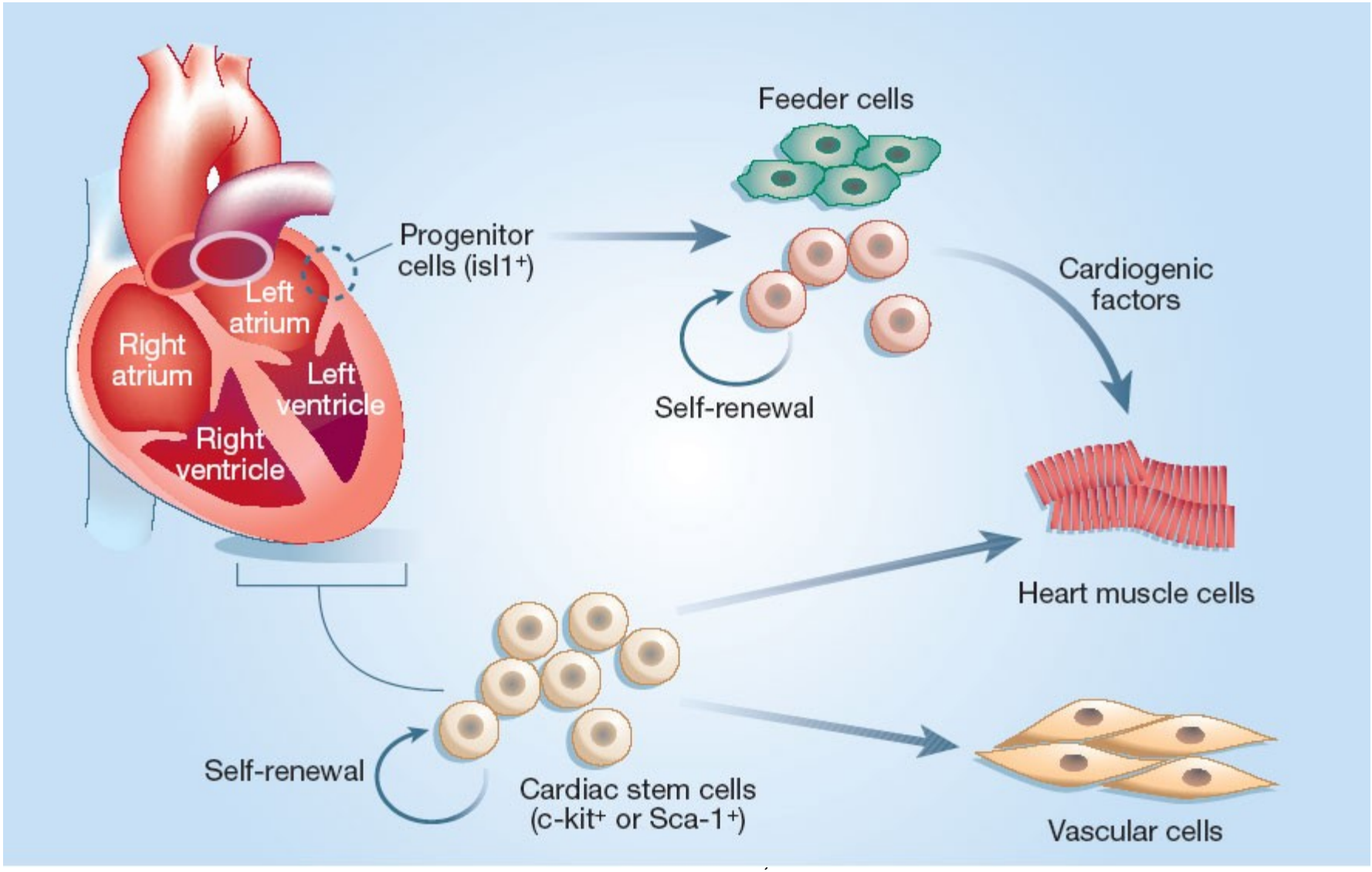


Figure 1.1. Differentiation of Human Tissues.

Embryonic and Adult Stem Cells



Cardiac Stem cells



Myocardial repair

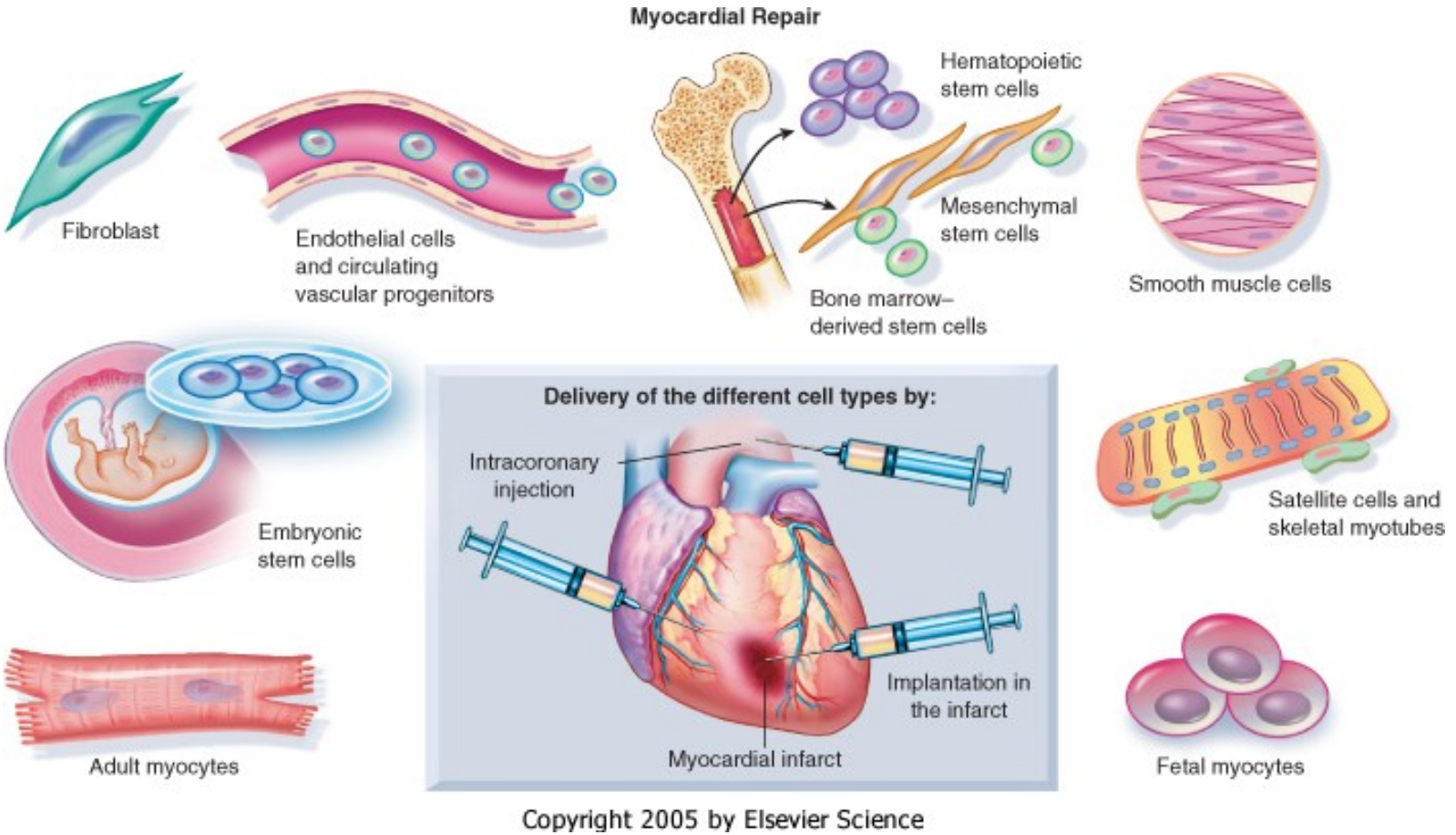
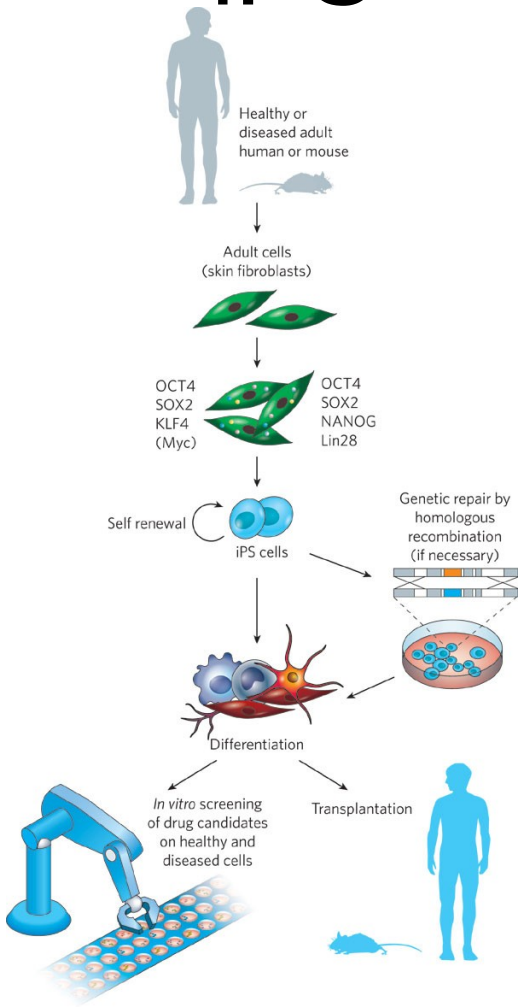
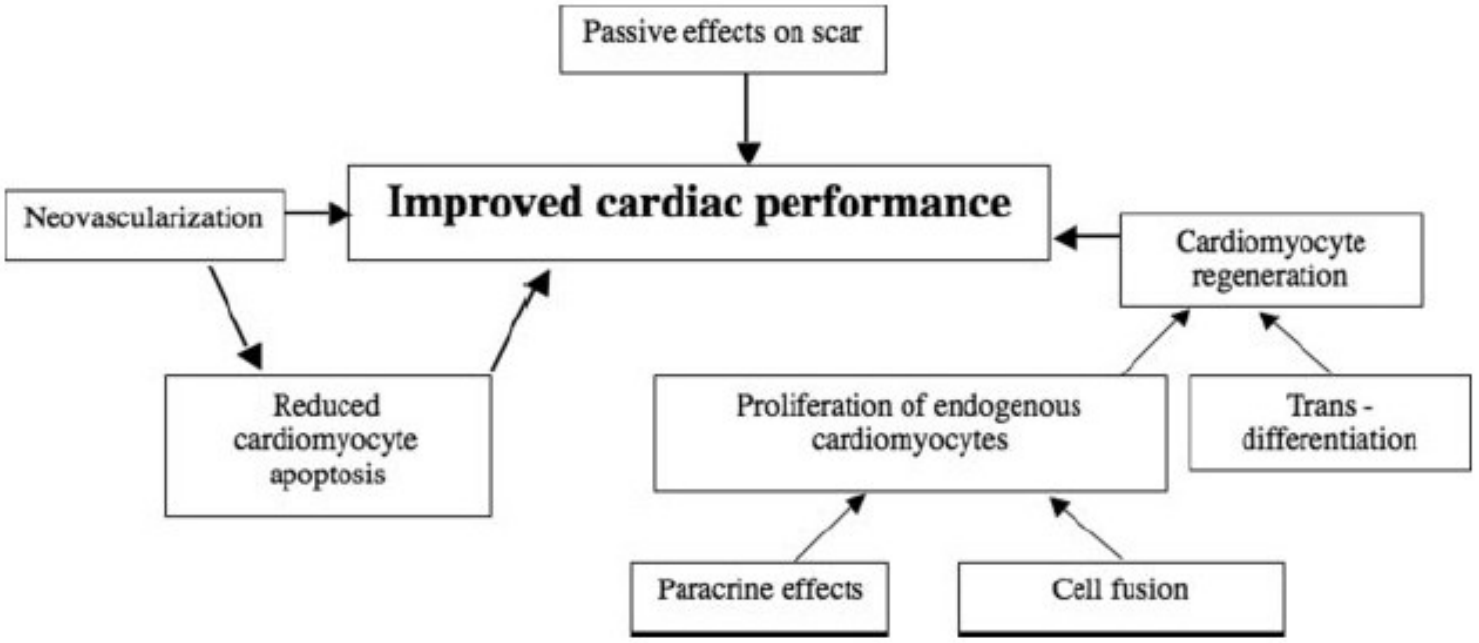


Figure 71-1

Induced Pluripotent Stem cells iPS

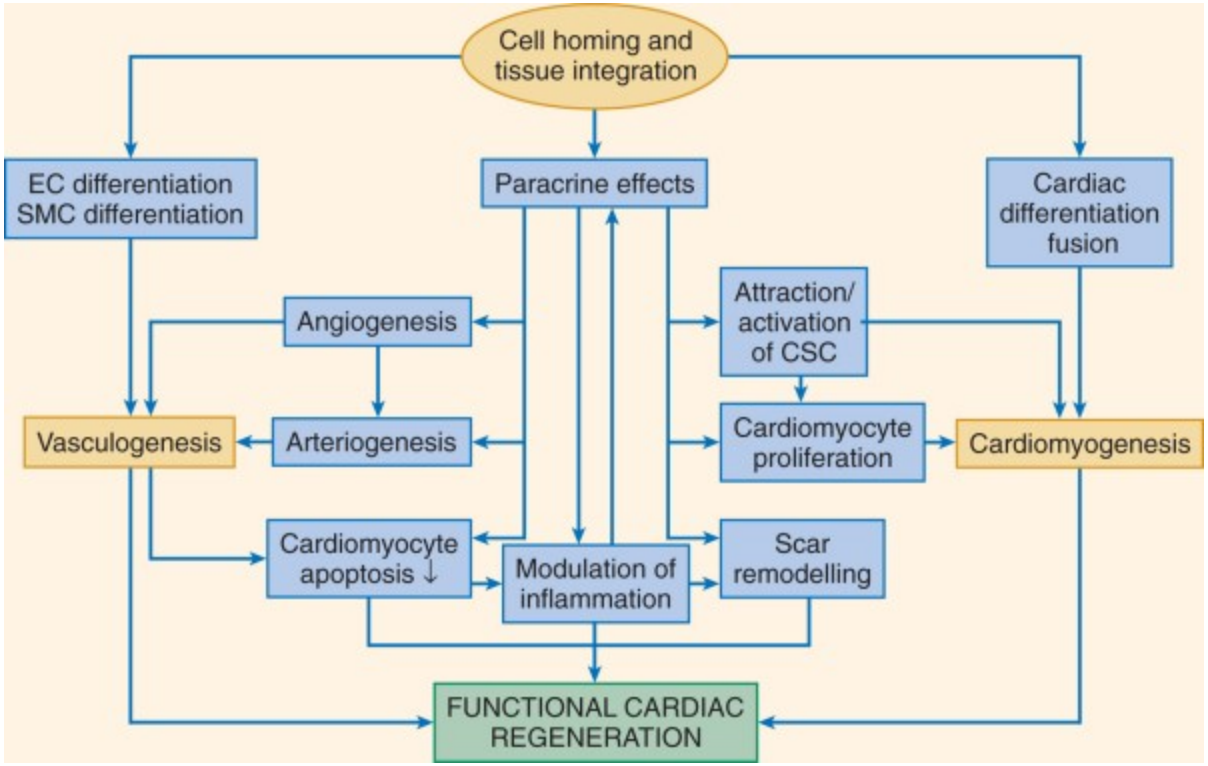


Possible mechanisms for successful cardiac regenerative therapy



Boyle et al Circulation 2006

FIGURE 29-3 Proposed mechanisms of action of stem/progenitor cells in cardiovascular repair.



Future directions

Braunwald 2008

- **"…. future therapies will likely be focused on reversing and/or stabilizing the downstream biological consequences of neurohormonal activation, rather than on neurohormonal activation per se."**

Sleeping Student:
Take home message

Overview of the pathophysiology of myocardial remodeling

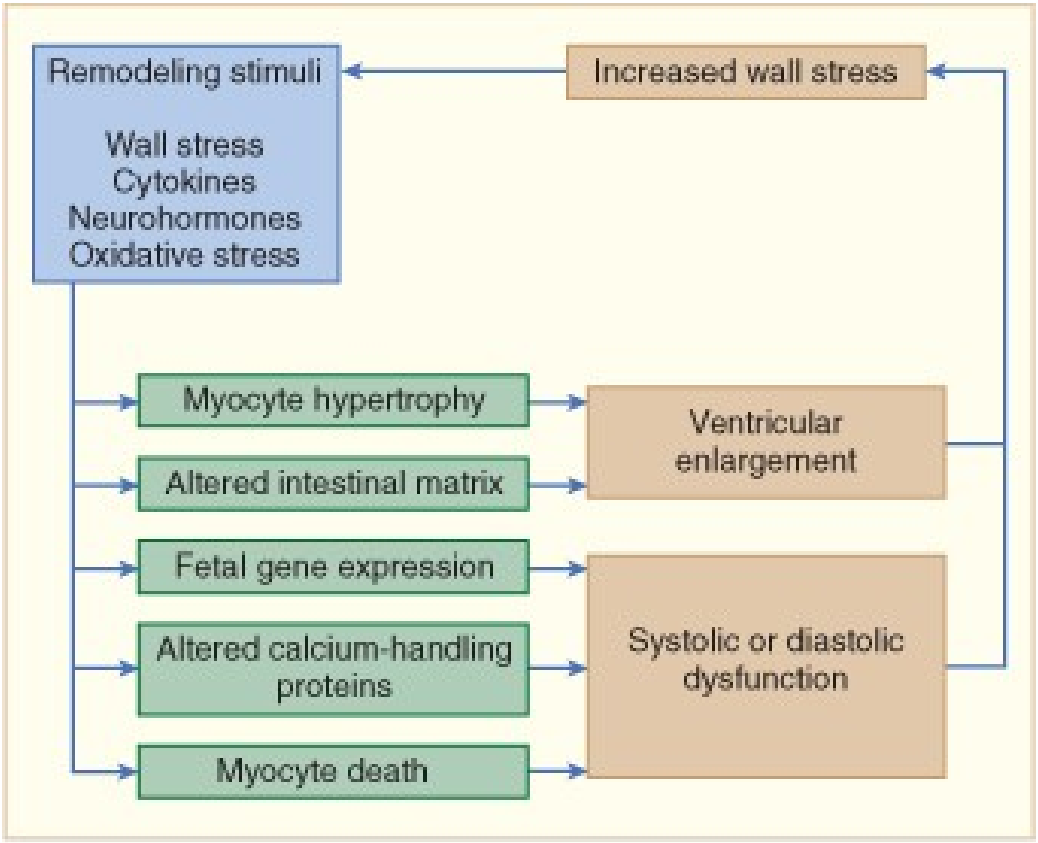


Figure 21-10