Exercise and Aging

MCB 135K

George A. Brooks
Integrative Biology, UCB

Outline

- I. Does Exercise Prevent Aging?
- II. Does Exercise Slow Aging or Compensate for Aging Effects?
- III. Why Exercise?
- IV. How to Exercise?

Does Exercise Prevent Aging?

- Yes?!
- No?!
- Exercise Slows Aging and Compensates for Aging Effects.

Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

Cardiovascular Fitness & Health

- Maximal Oxygen Consumption (VO_2max) is the standard for cardiovascular fitness
- VO_2max is increased by regular, prolonged exercise
- VO_2max declines with aging, but can be maintained at high levels despite advancing years.

Leg Cycler Ergometer Evaluation of Maximal O_2 Consumption (VO_2max)

QuickTime™ and a
Motion JPEG OpenDML decompressor
are needed to see this picture.

Treadmill Evaluation of Maximal O_2 Consumption (VO_2max)

Treadmill Evaluation of a Cardiac Patient-Exercise Stress Test

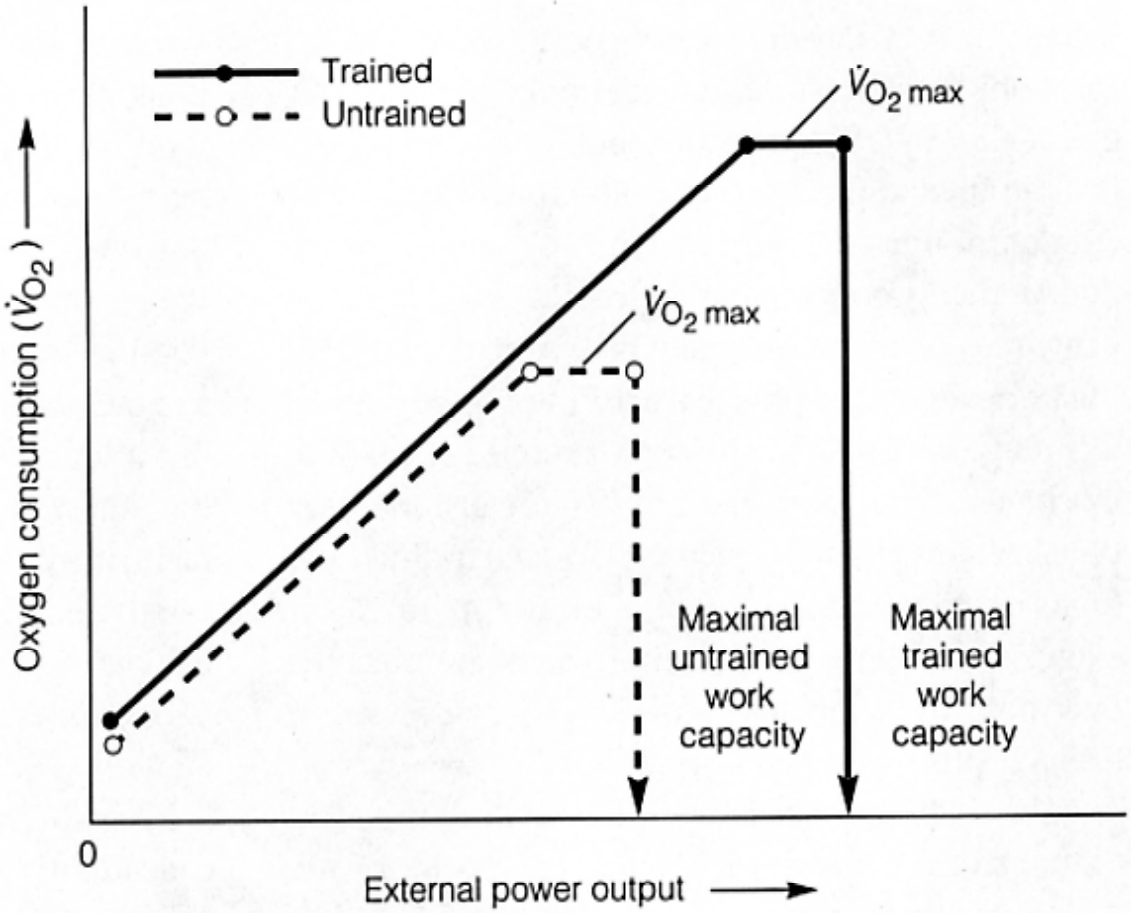

Figure 1-7 Relationship between oxygen consumption ($\dot{V}_{O_2}$) and external work rate (power output). In response to increments in power output, both trained and untrained individuals respond with an increase in $\dot{V}_{O_2}$. The greater ability of trained individuals to sustain a high power output is largely due to a greater maximal O_2 consumption ($\dot{V}_{O_2max}$).

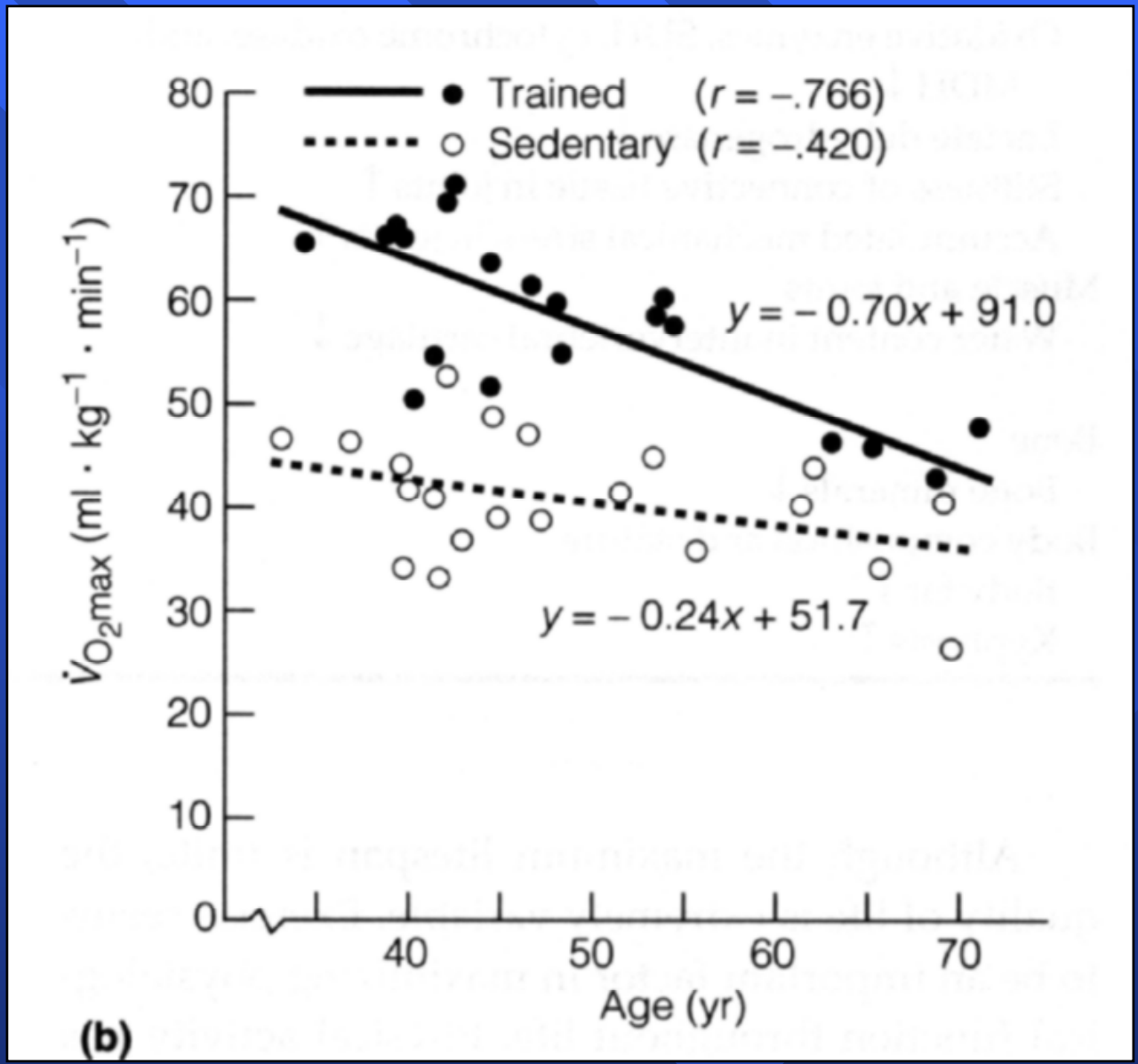

Figure 32-1 (b) y = V_{O2max} (ml • kg $^{-1}$ • min $^{-1}$). Although training will improve V_{O2max} and the quality of life in the elderly, it will not prevent indefinitely the decline in functional capacity. x = age (hr). Adapted from Suominen et al., 1980.

Cardiovascular Fitness & Health

- Regular prolonged exercise offers protection against having cardiovascular disease (Decreases Morbidity)
- Regular prolonged exercise offers protection against dying from cardiovascular disease (Decreases Mortality)

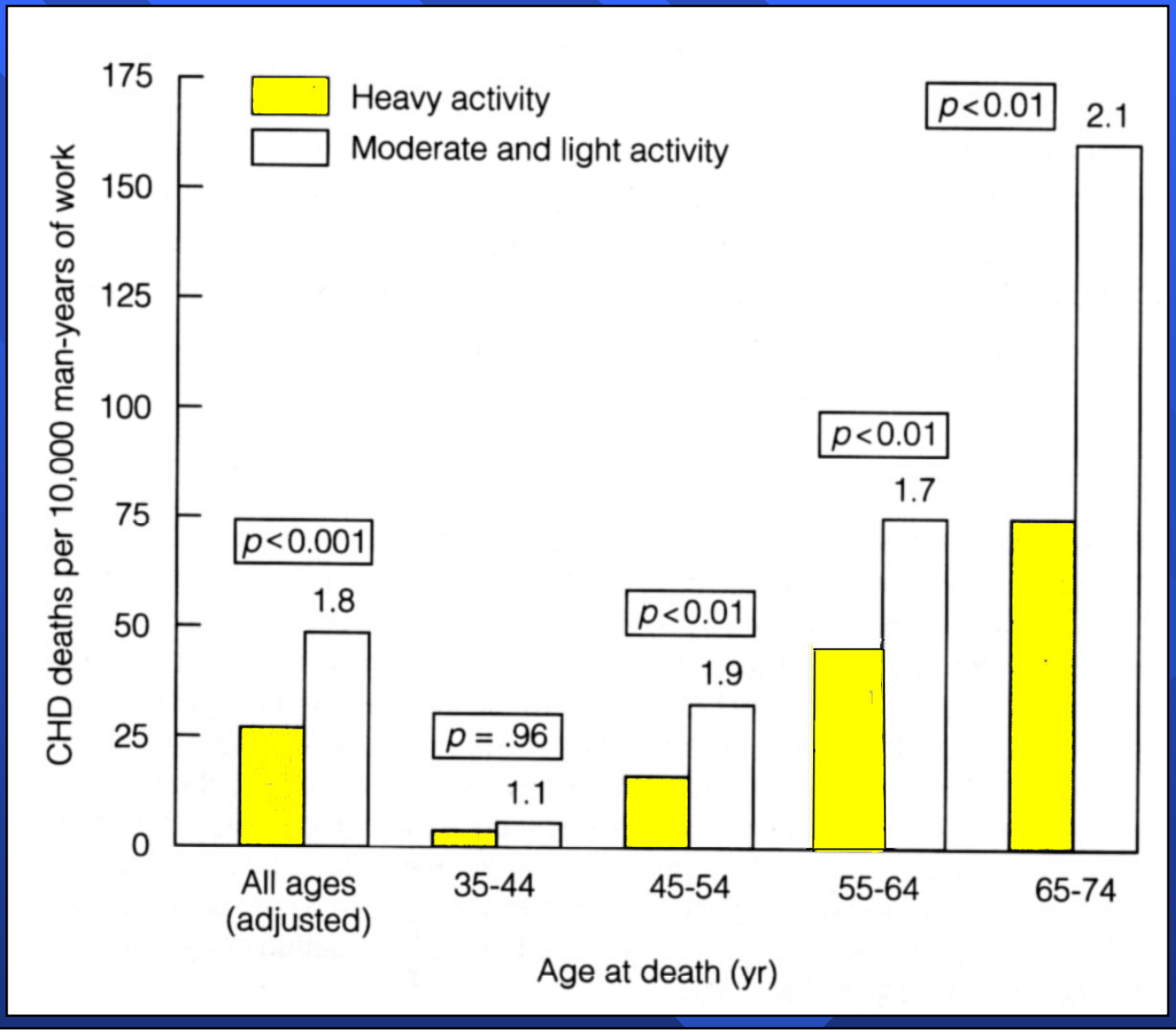

Figure 24-6 Deaths from CHD in longshoremen according to physical activity of work (range in kcal • min-1) and age at death. Shaded bars = heavy activity (5.2 - 7.5 kcal • min-1); unshaded bars = moderate and light activity (1.5 - 5.0 kcal • min-1). The relative risk of developing CHD for moderate and light exercise groups compared to heavy exercise groups given above bars. Adapted from Paffenbarger and Hale, 1975.

Why Exercise?

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- Metabolic Fitness & Health
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- Sense of Well Being

Metabolic Fitness & Health

- Regular Physical Exercise Helps to Control Age -Related Increases in Body Fatness
- Regular Physical Exercise Reduces the Incidence and Severity of Type II Diabetes (NIDDM).

U.S. Obesity Trends in Adults

From 1991-1998,

2000

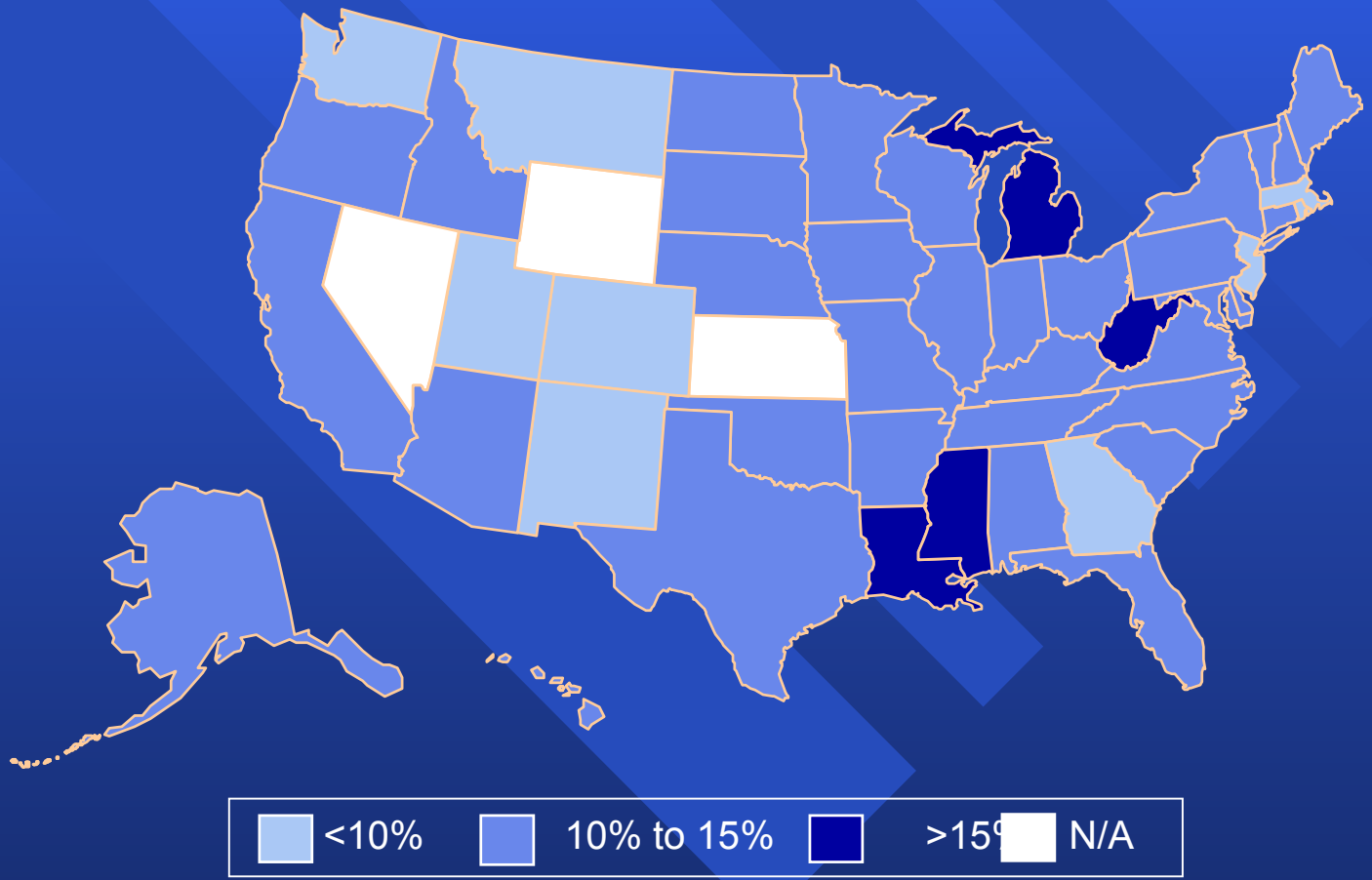
Source: Mokdad AH, Serdula MK,
JAMA, October 27, 1999; 282

Source: Mokdad A H, et al. *JA*

Prevalence of Obesity* Among U.S. Adults

BRFSS, 1991

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



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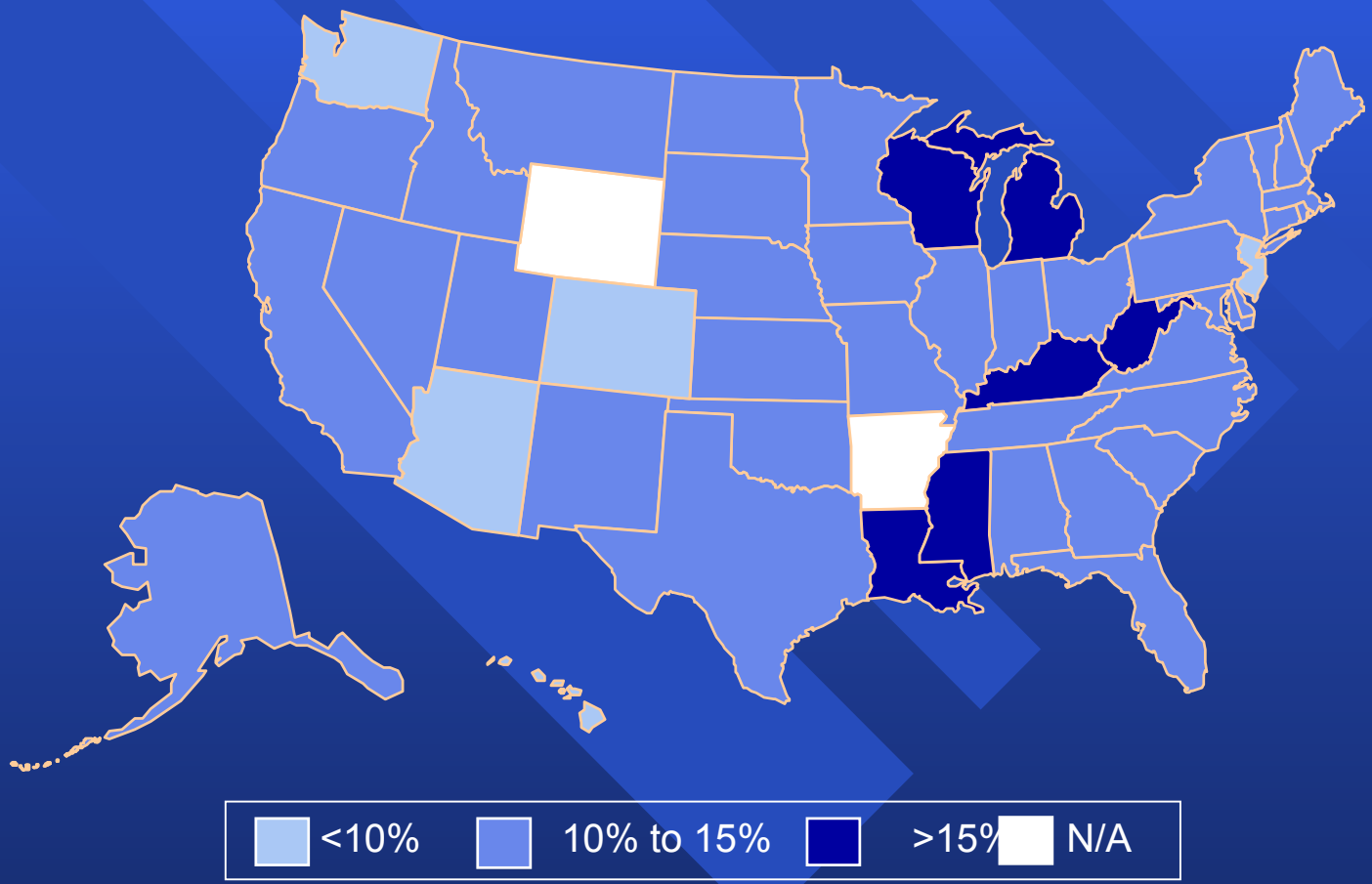

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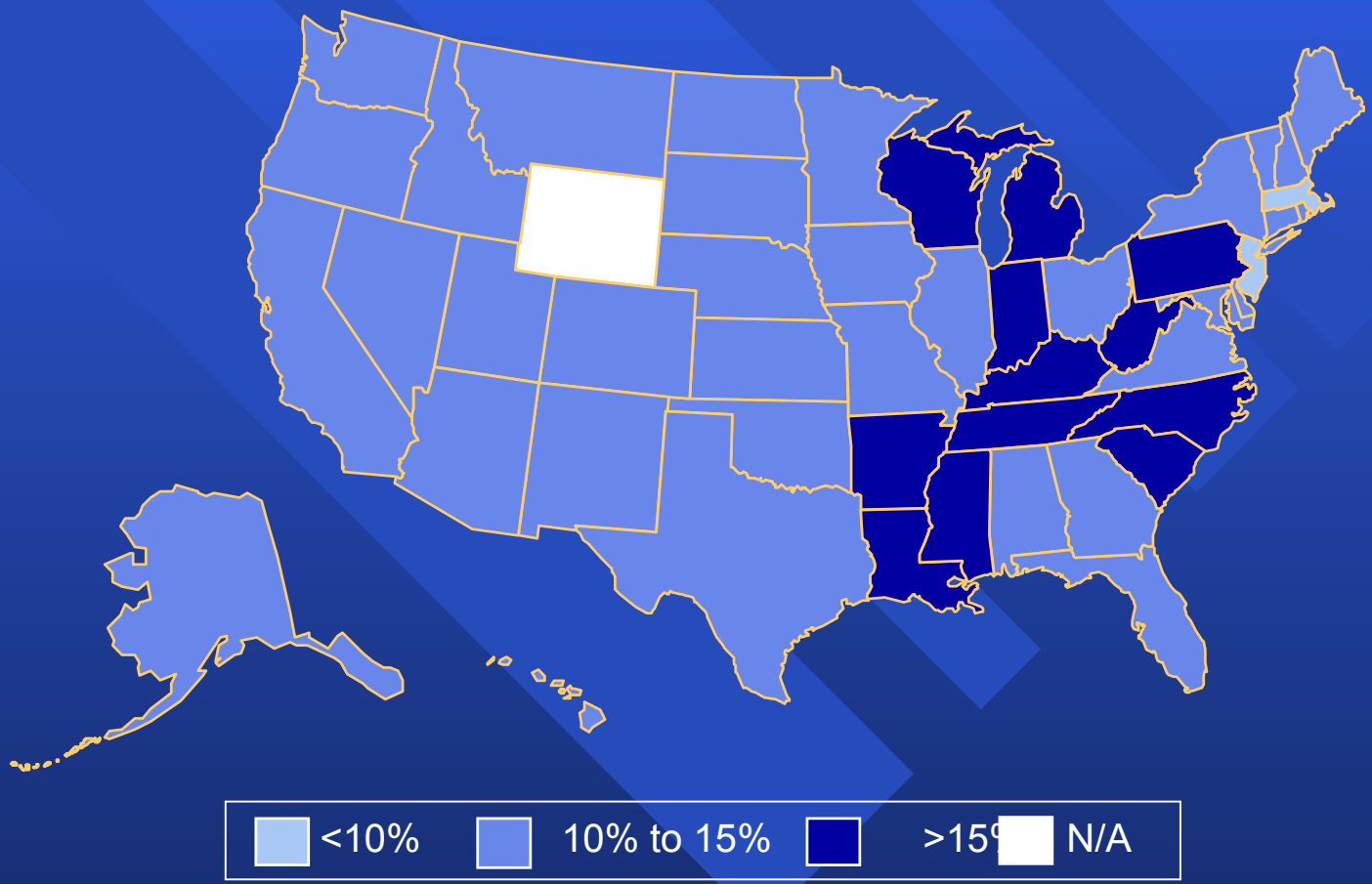

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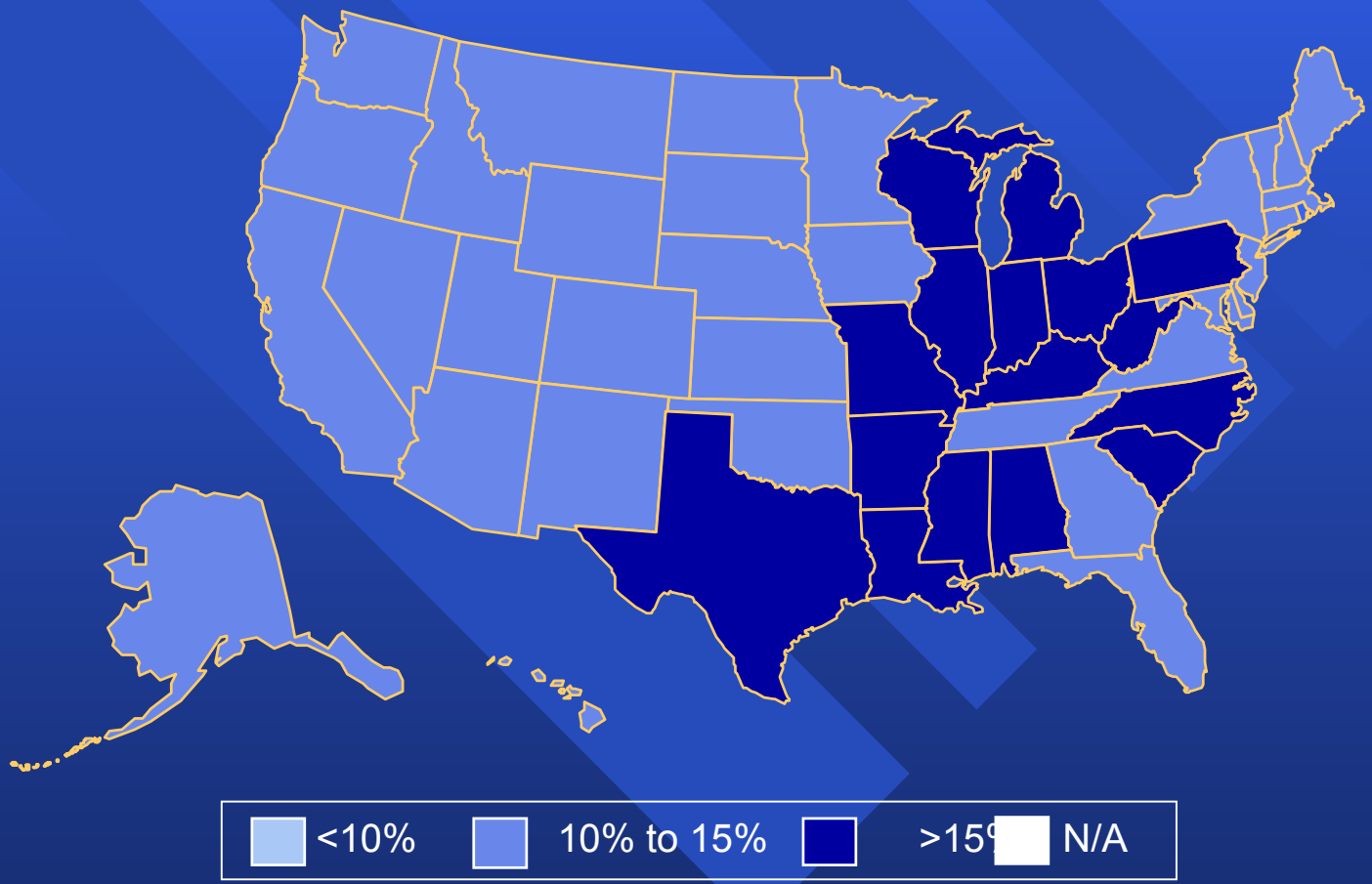

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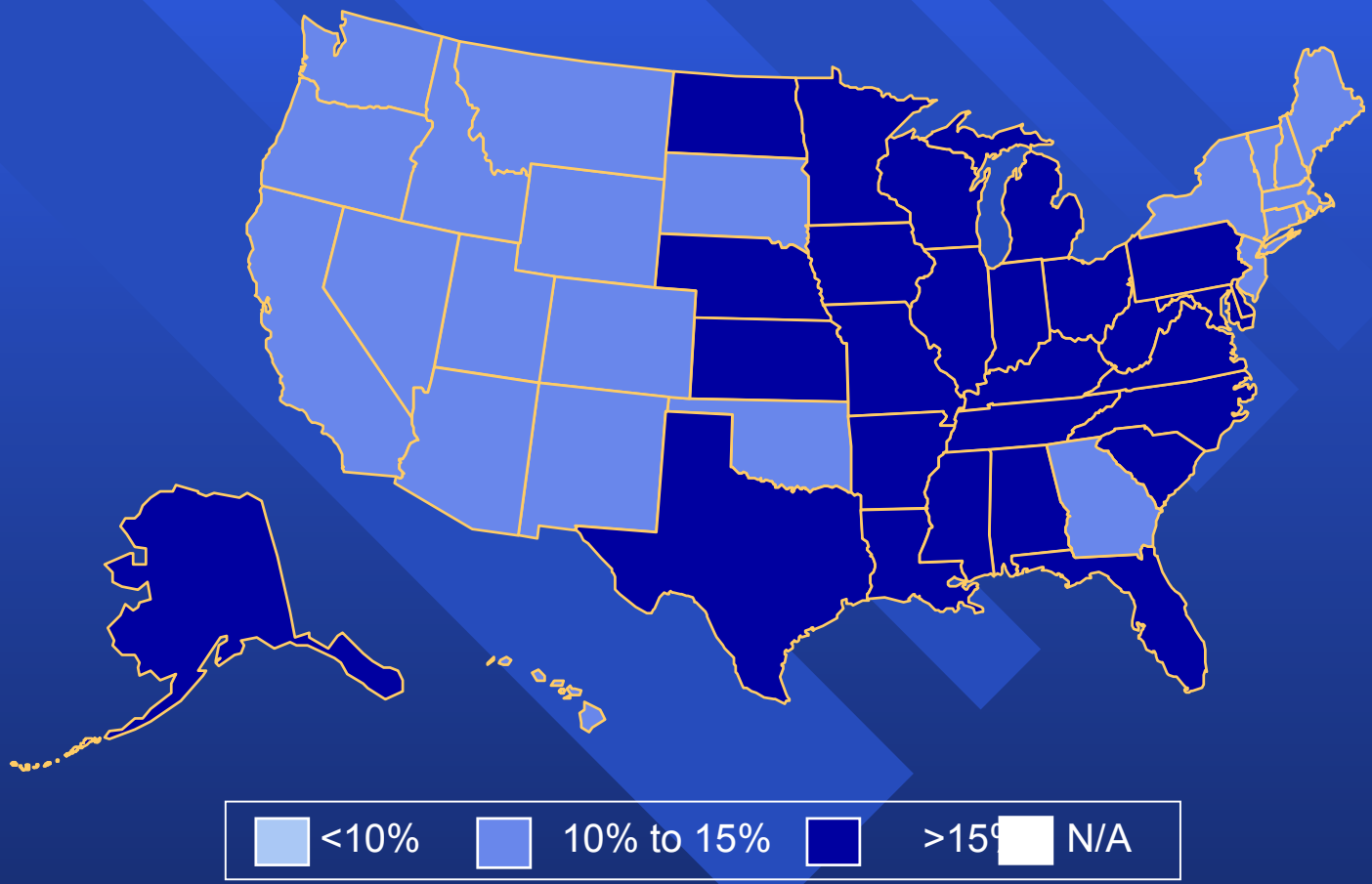

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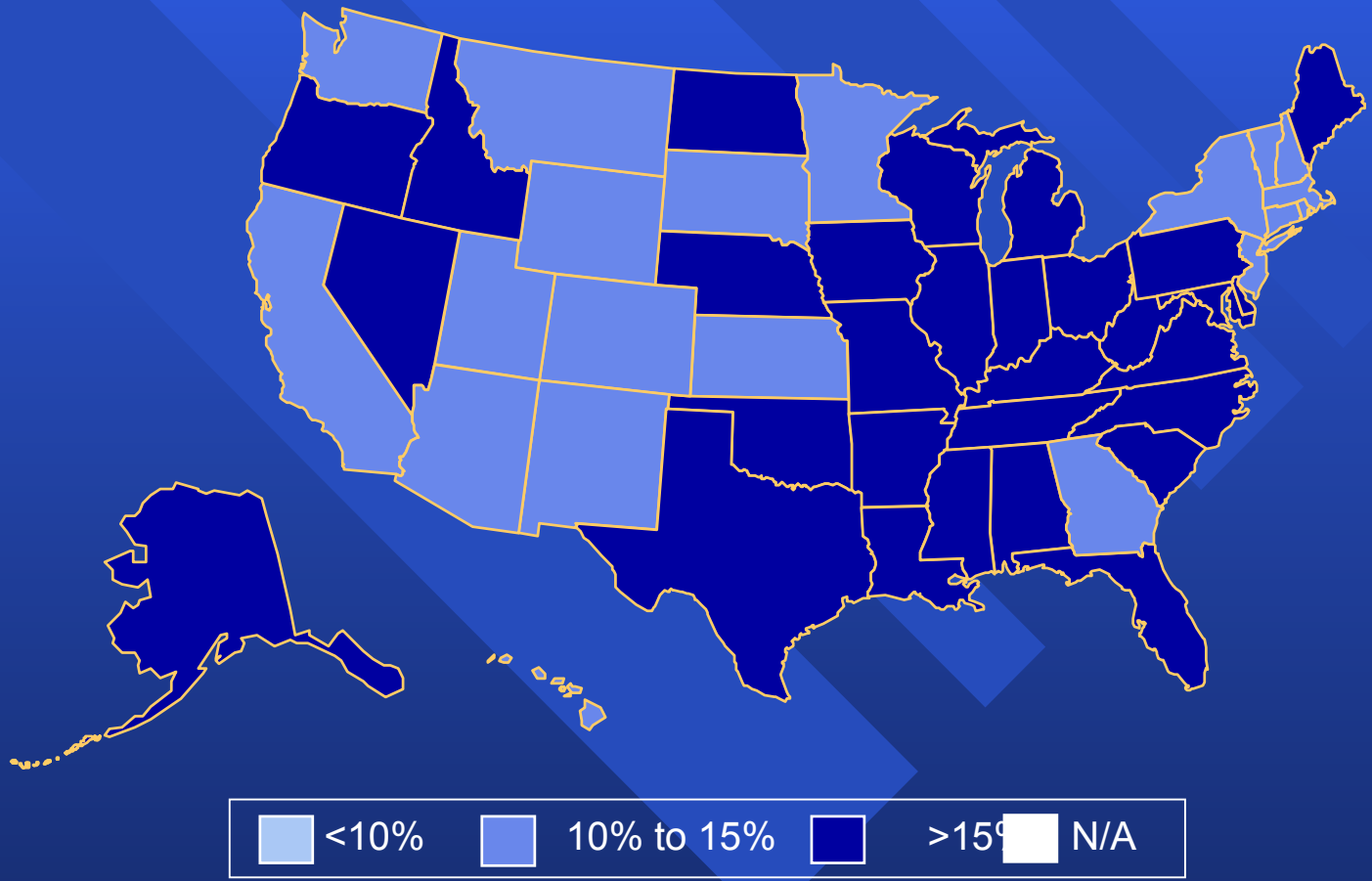
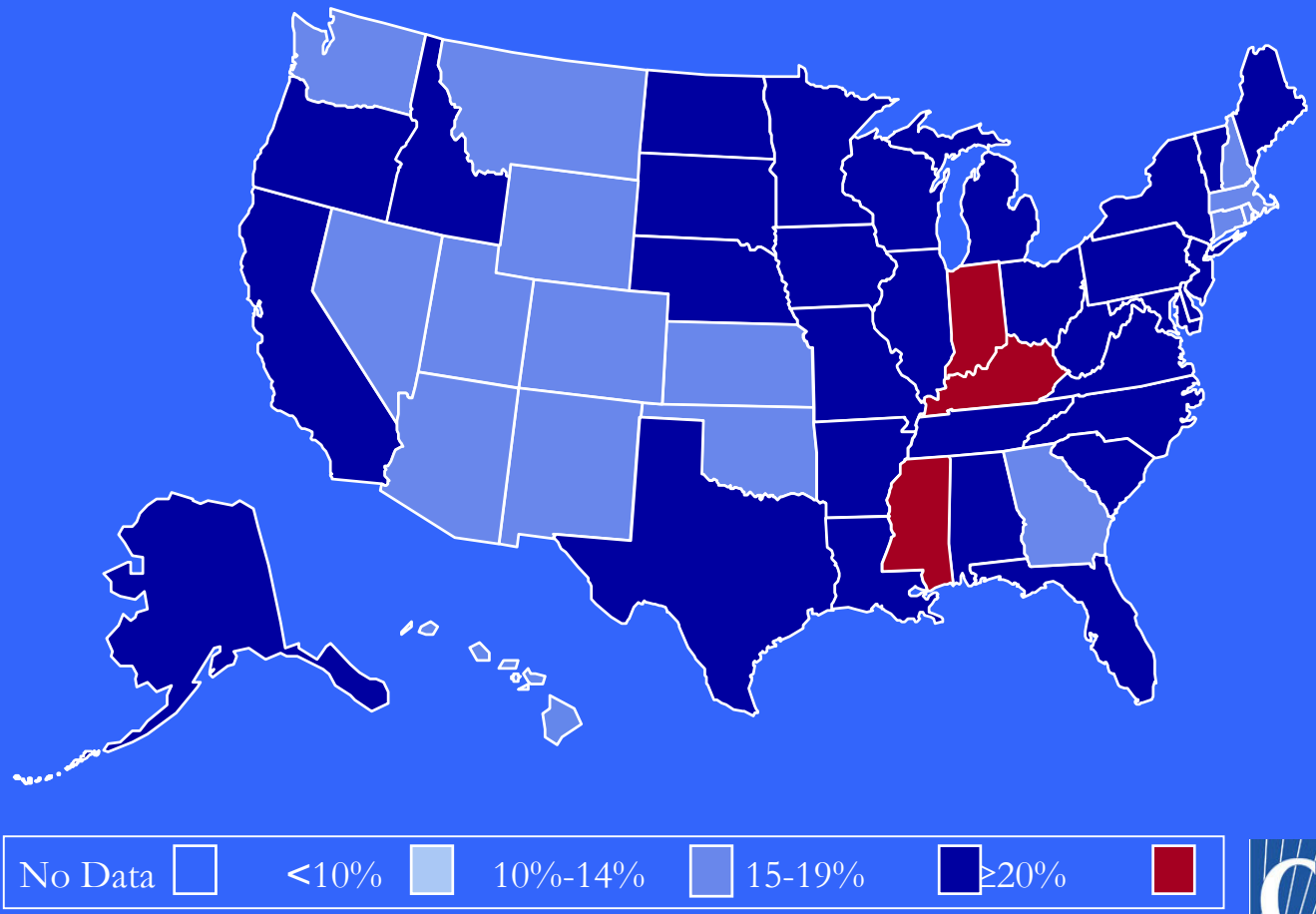


Prevalence of Obesity* Among U.S. Adults

BRFSS, 1997

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



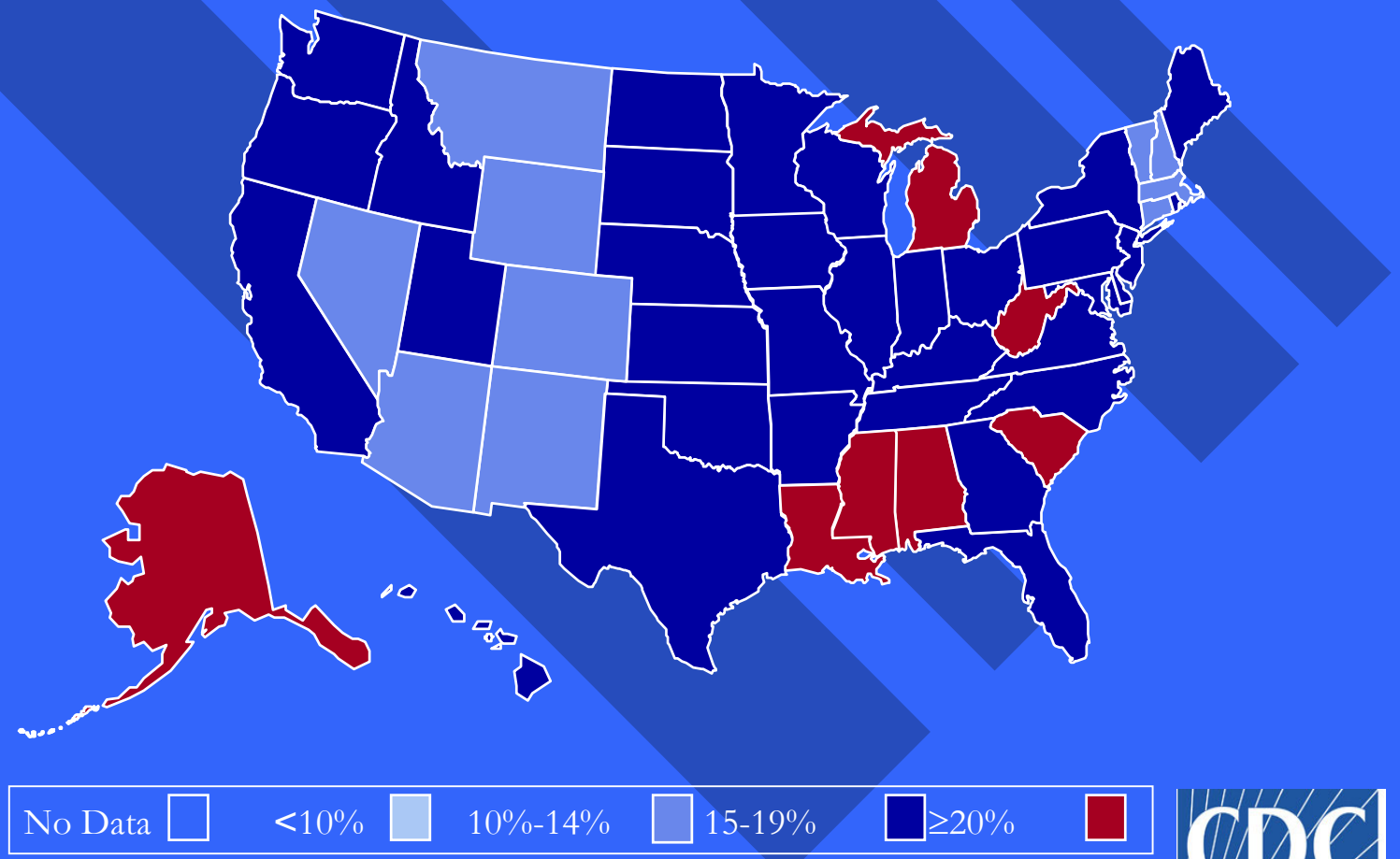
Source: BRFSS, CDC.

CDC
Centers for Disease Control and Prevention

Prevalence of Obesity* Among U.S. Adults

BRFSS, 1998

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



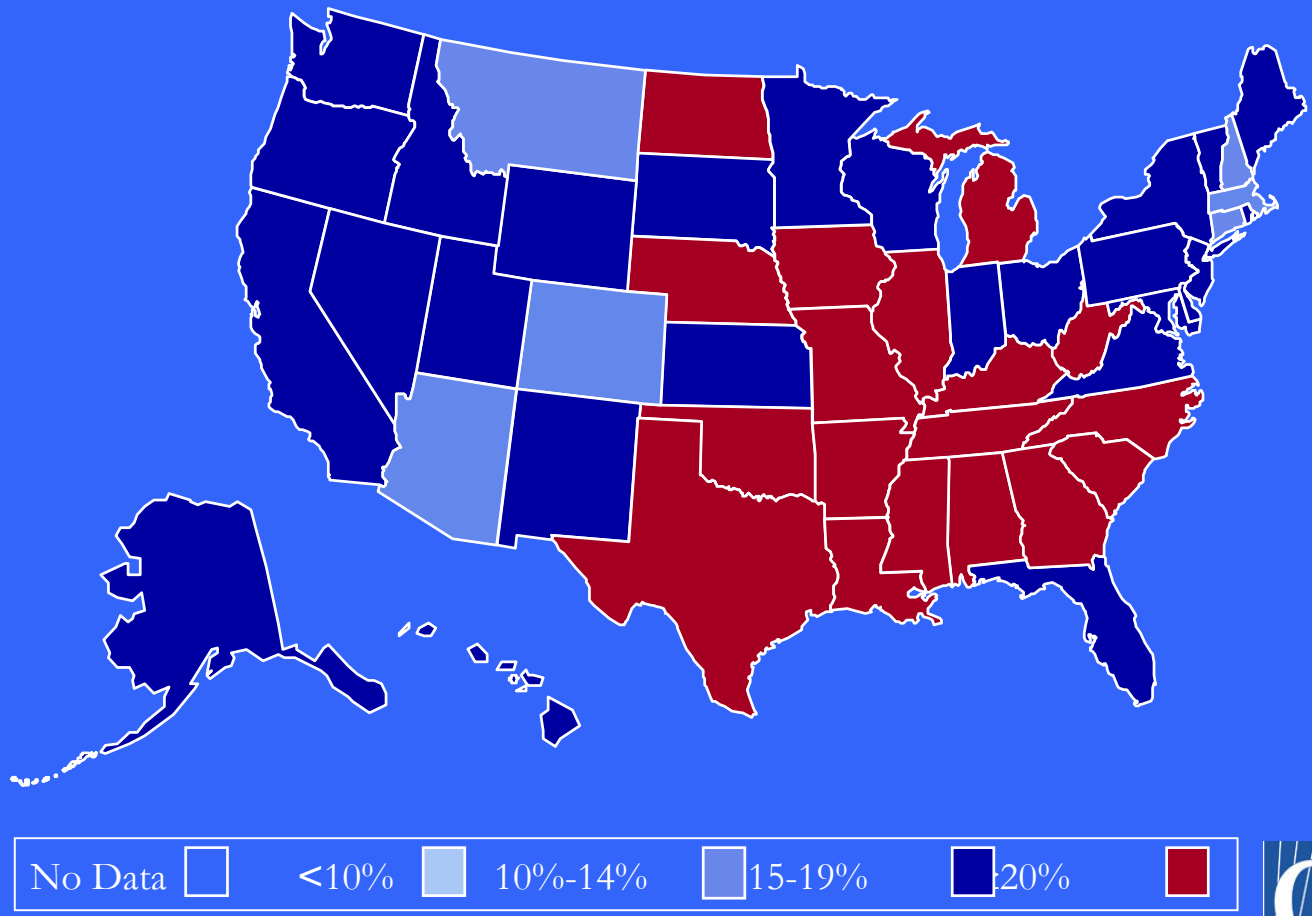
Source: BRFSS, CDC

CDC
Centers for Disease Control and Prevention

Prevalence of Obesity* Among U.S. Adults

BRFSS, 1999

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



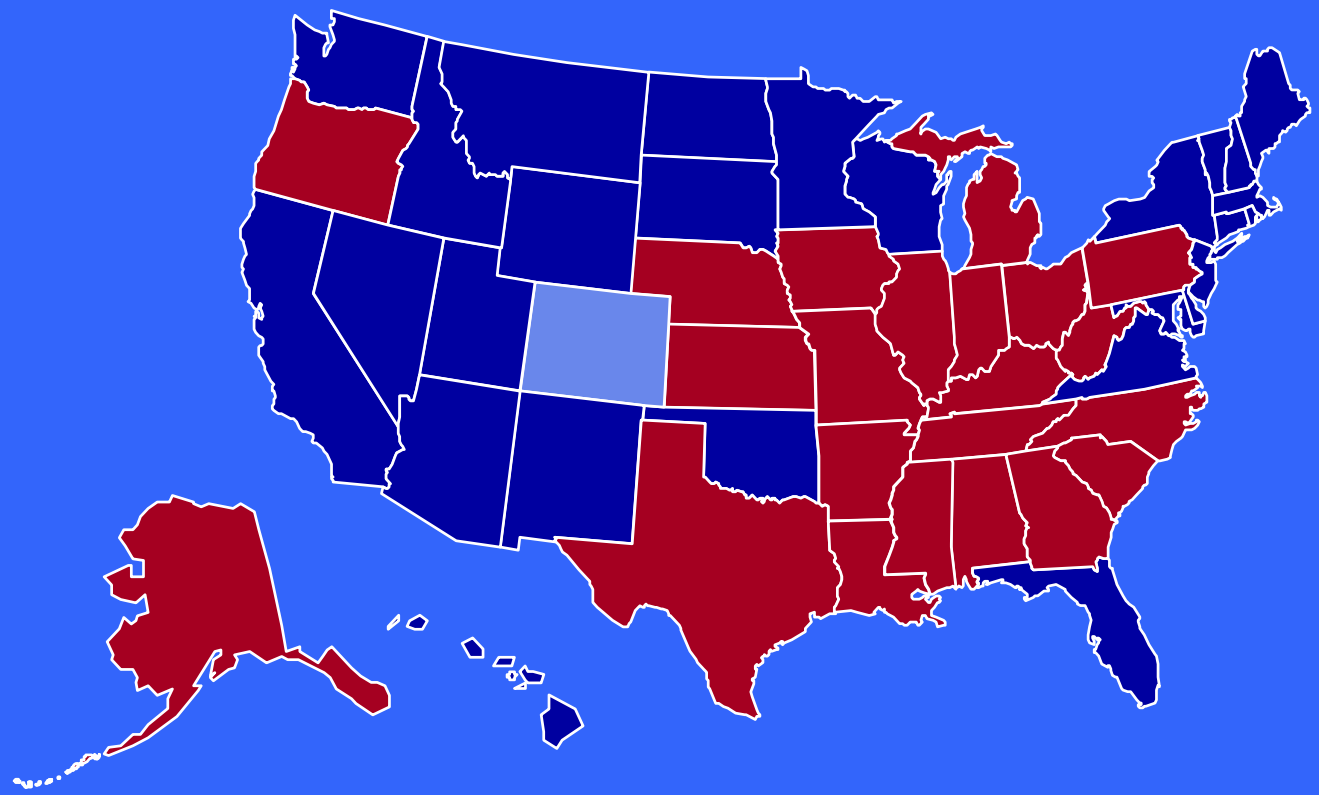
Source: BRFSS, CDC.

CDC
Centers for Disease Control and Prevention

Prevalence of Obesity* Among U.S. Adults

BRFSS, 2000

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



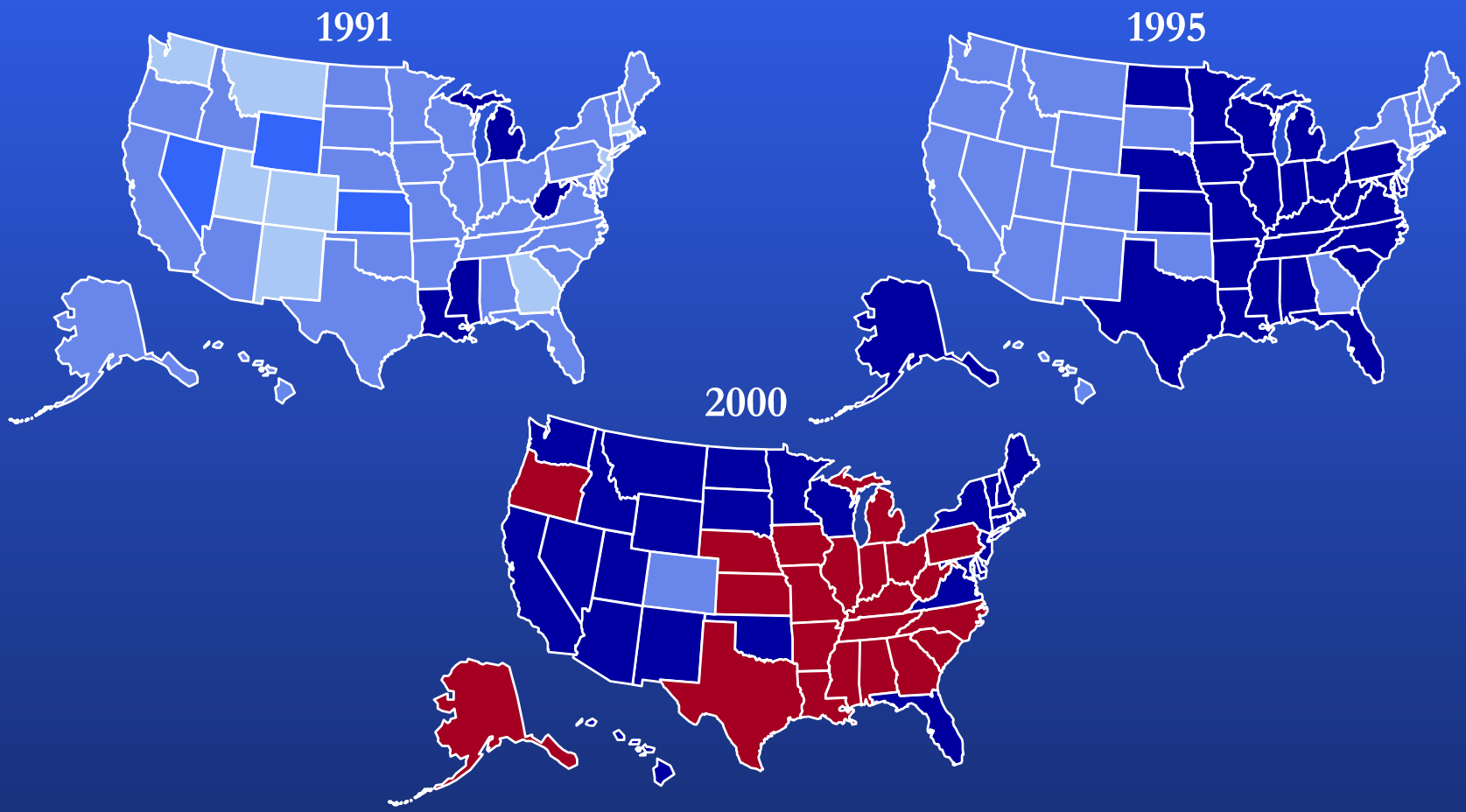
Source: Mokdad A H, et al. *JAMA* 1999;282:16, 2001;286:10.

CDC
Centers for Disease Control and Prevention

Obesity* Trends Among U.S. Adults

BRFSS, 1991, 1995 and 2000

(*BMI ≥ 30, or ~ 30 lbs. overweight for 5'4" person)



Source: Mokdad A H, et al. *JAMA* 1999;282:16, 2001;286:10.

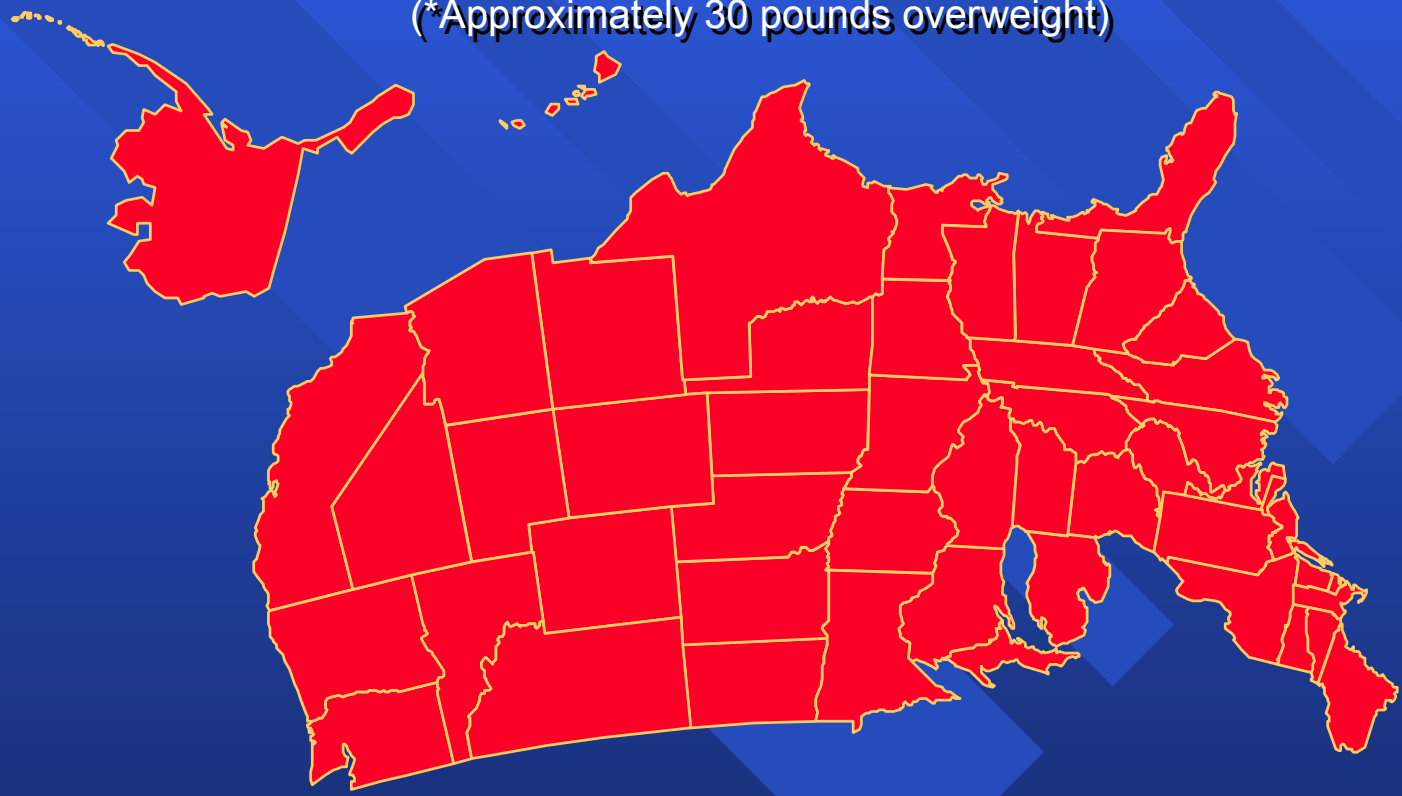
CDC
Centers for Disease Control and Prevention

Krispy Kreme vs. NIH & CDC Imbalance

Prevalence of Obesity* Among U.S. Adults

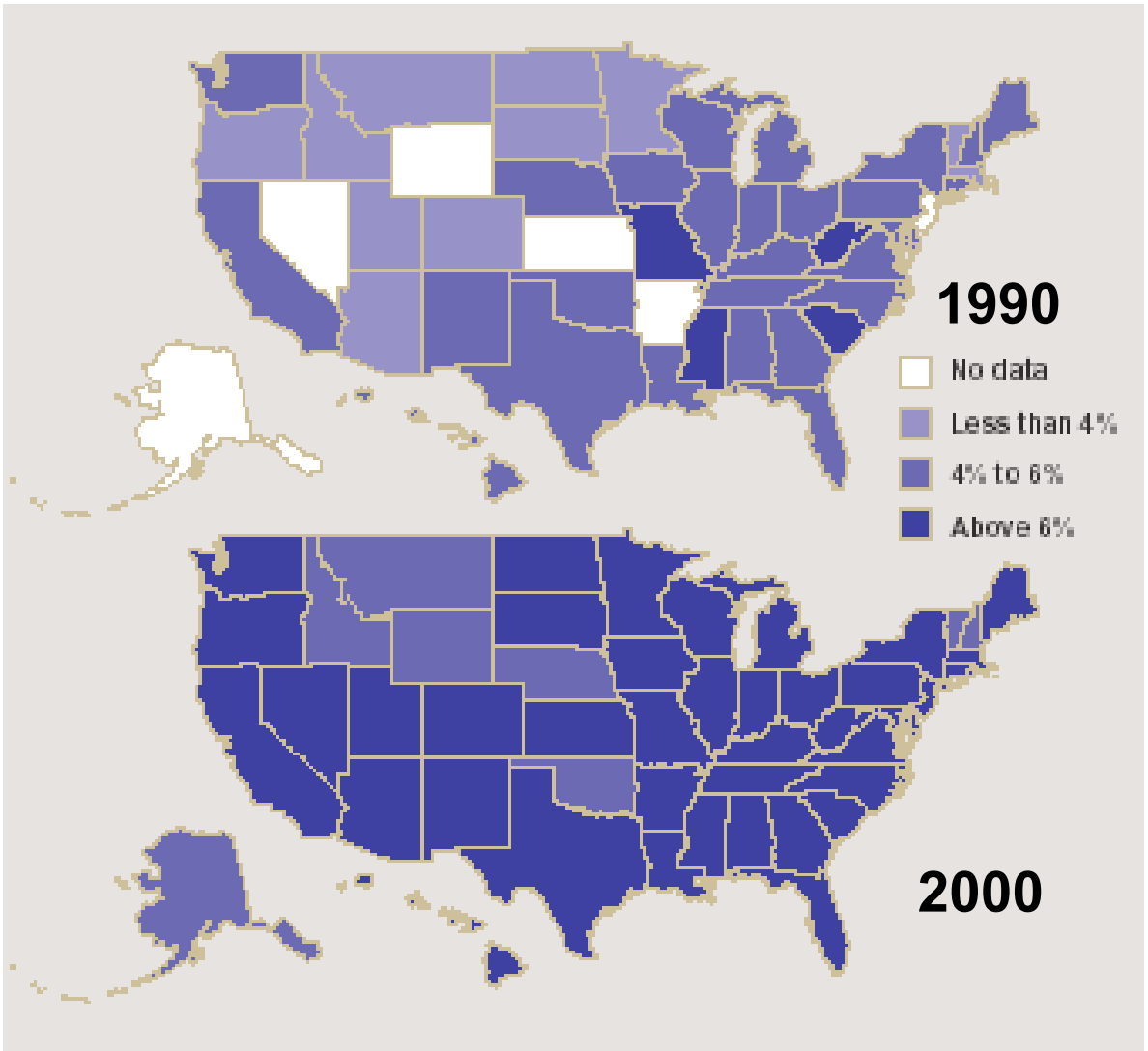
BRFSS, 20??

(*Approximately 30 pounds overweight)



No Data | <10% | 10%-14% | 15-19% | ≥20%

CDC
Centers for Disease Control and Prevention



A darkening scene. The percentage of adults with diabetes increased throughout the United States between 1990 (top) and 2000 (bottom).

Pimas

1900

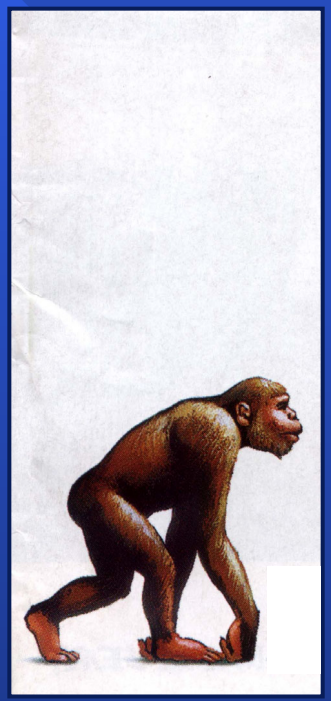
2000

From: J. Marx, Science 296: 686, 2002.

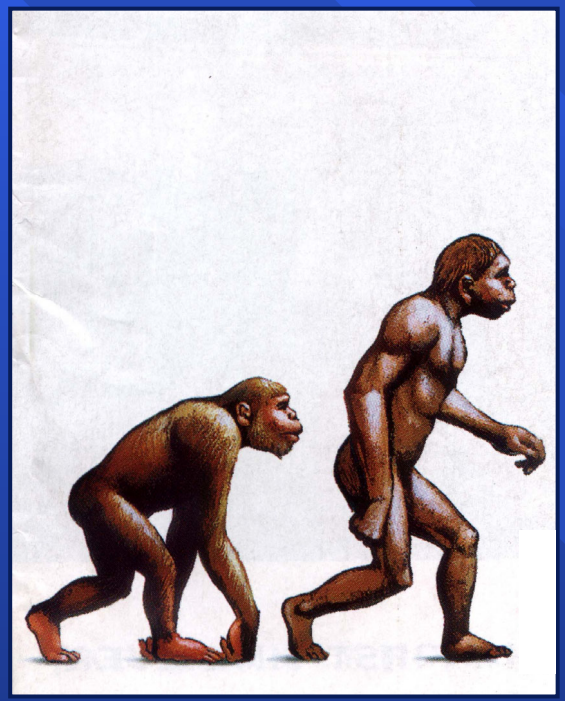
Daily Cal (3/12/03)

Councilmember Miriam Hawley (right) tests out the Segway Human Transporter in front of the Civic Center Tuesday with the help of Stacy Ferguson (left), Segway's director of public affairs. "It's a wonderful thing (the Segway)," Hawley said. "I think it's a great mobility device."

Human Evolution



Human Evolution



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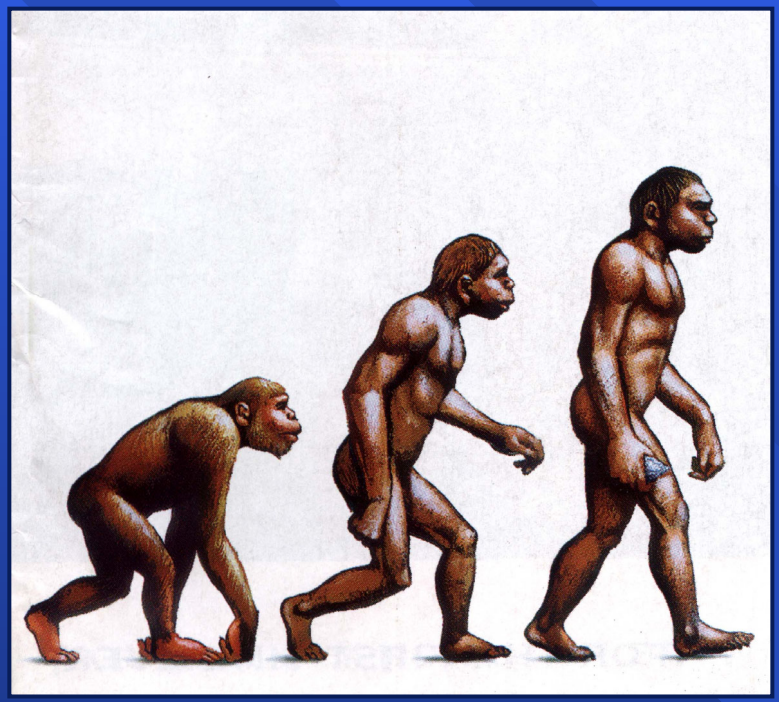

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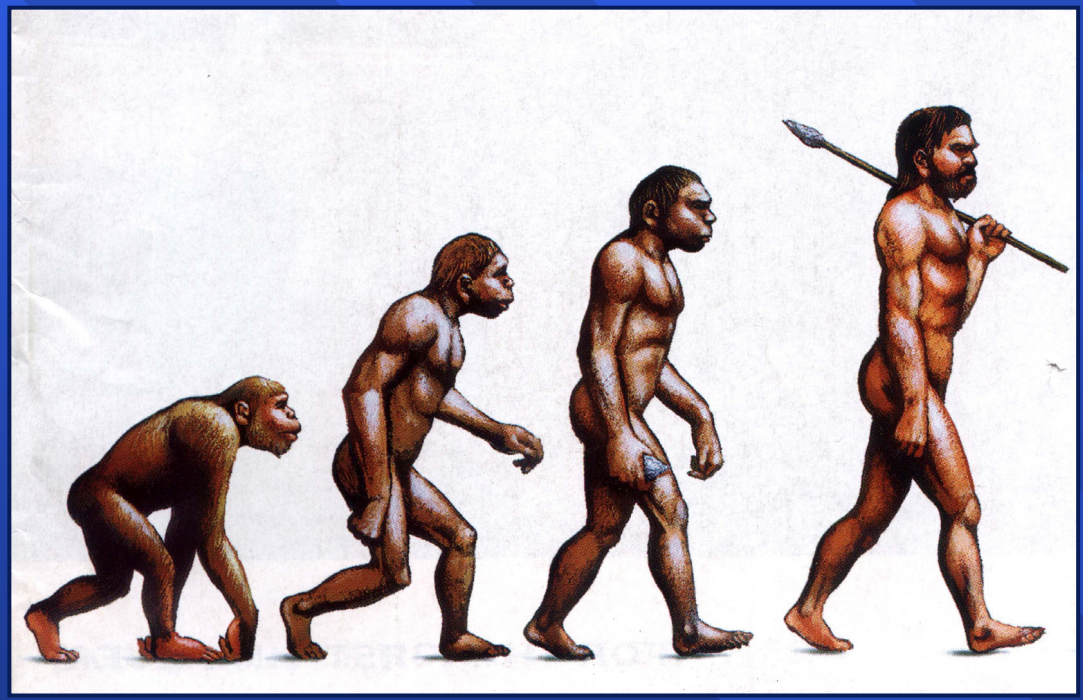

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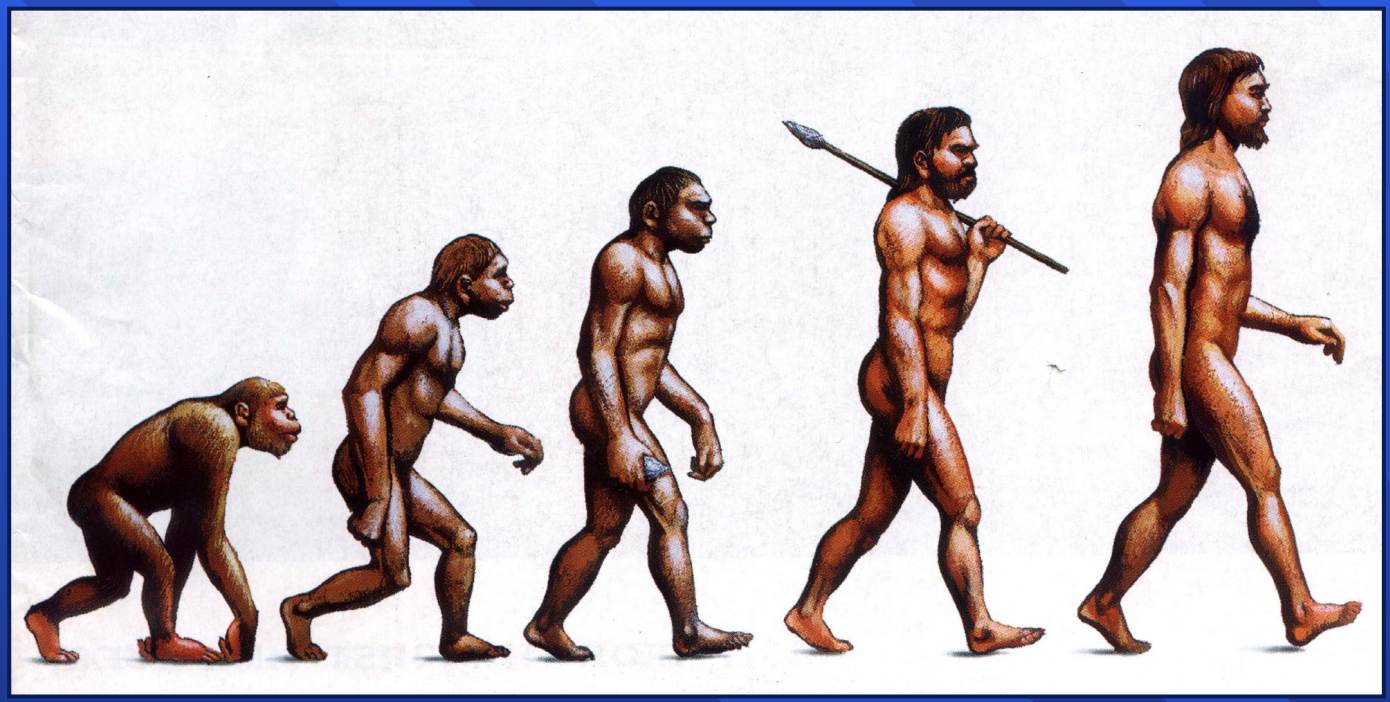
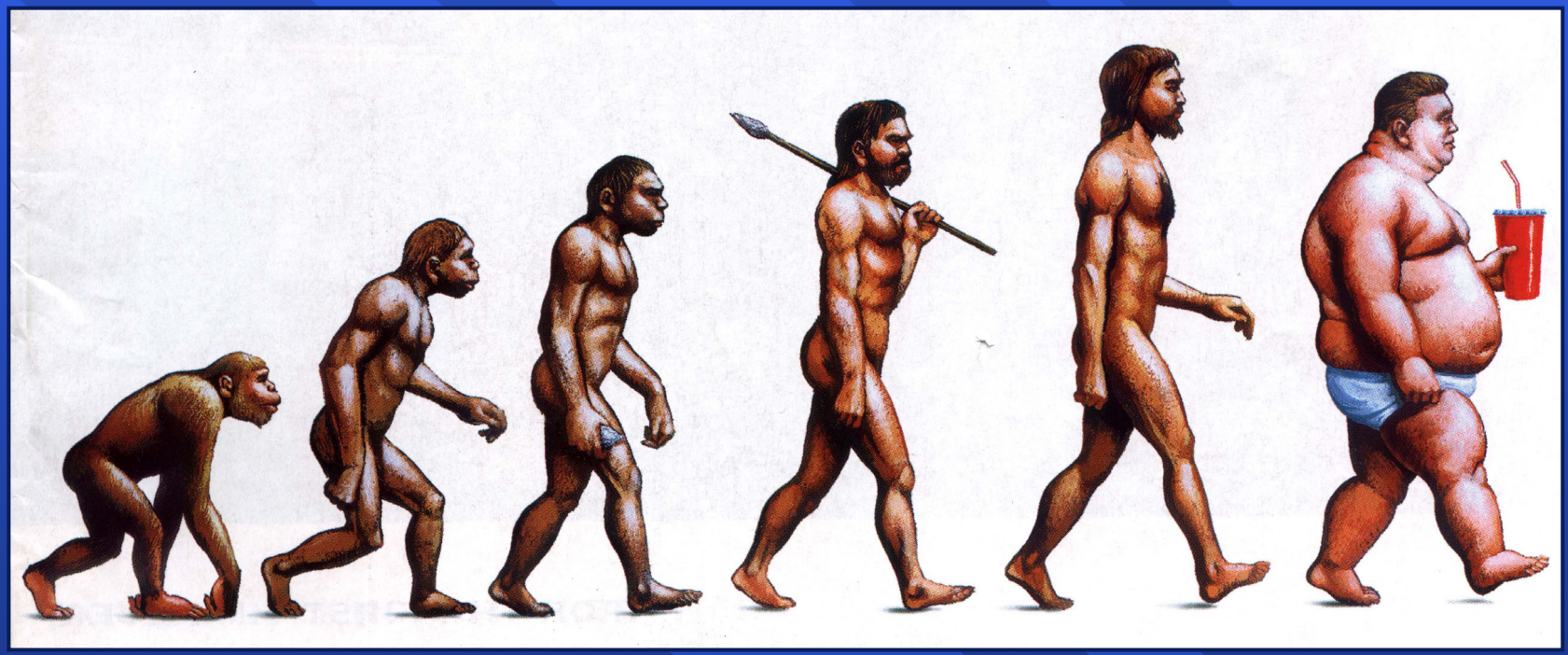


Ape to American



Human Dysevolution

Fat is a Wonderful Energy Storage Form,

Butt is a risk factor for chronic diseases.

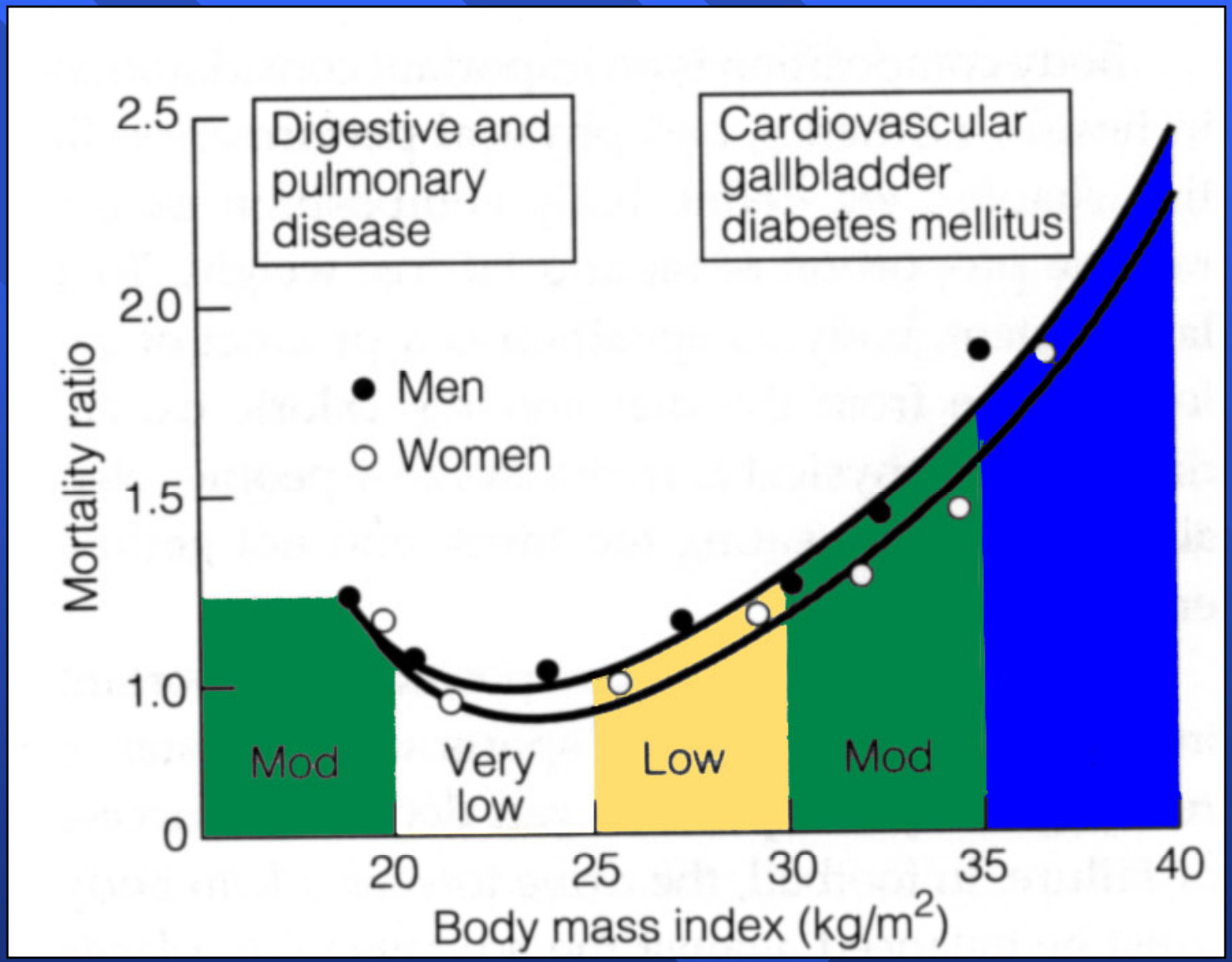
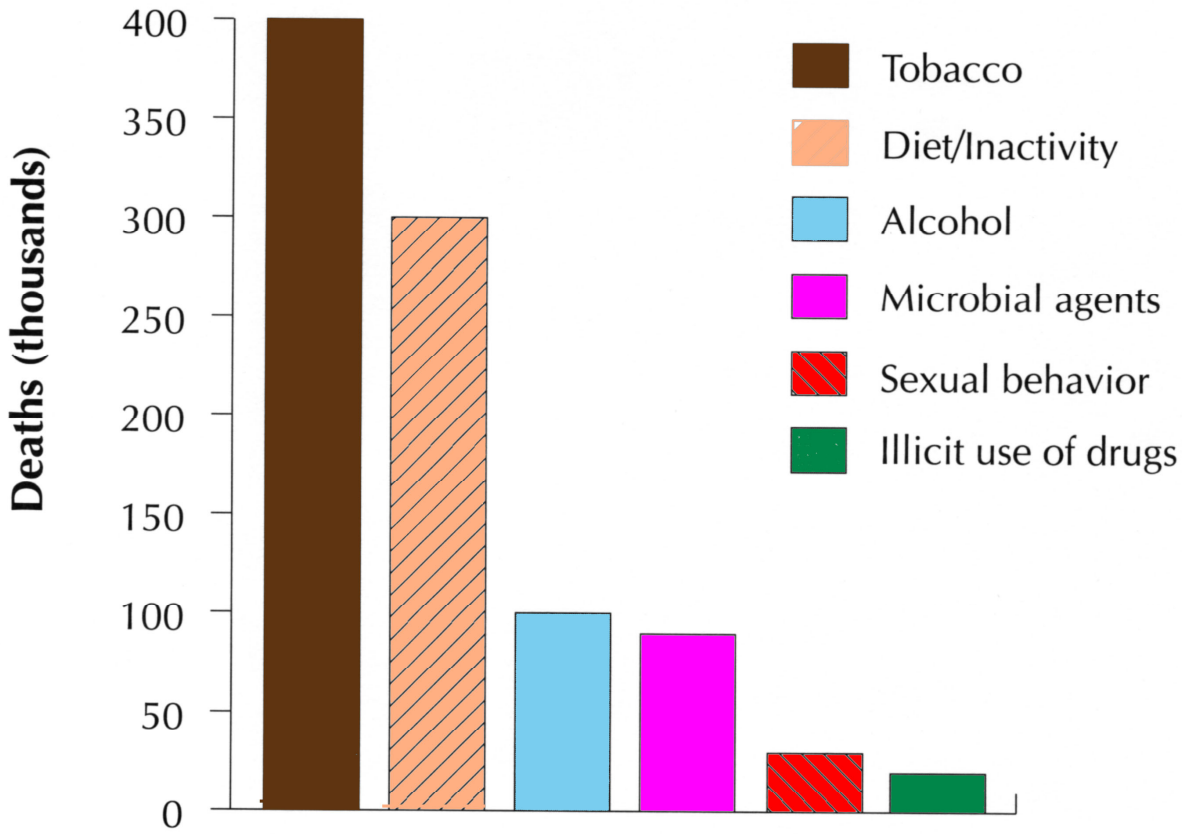


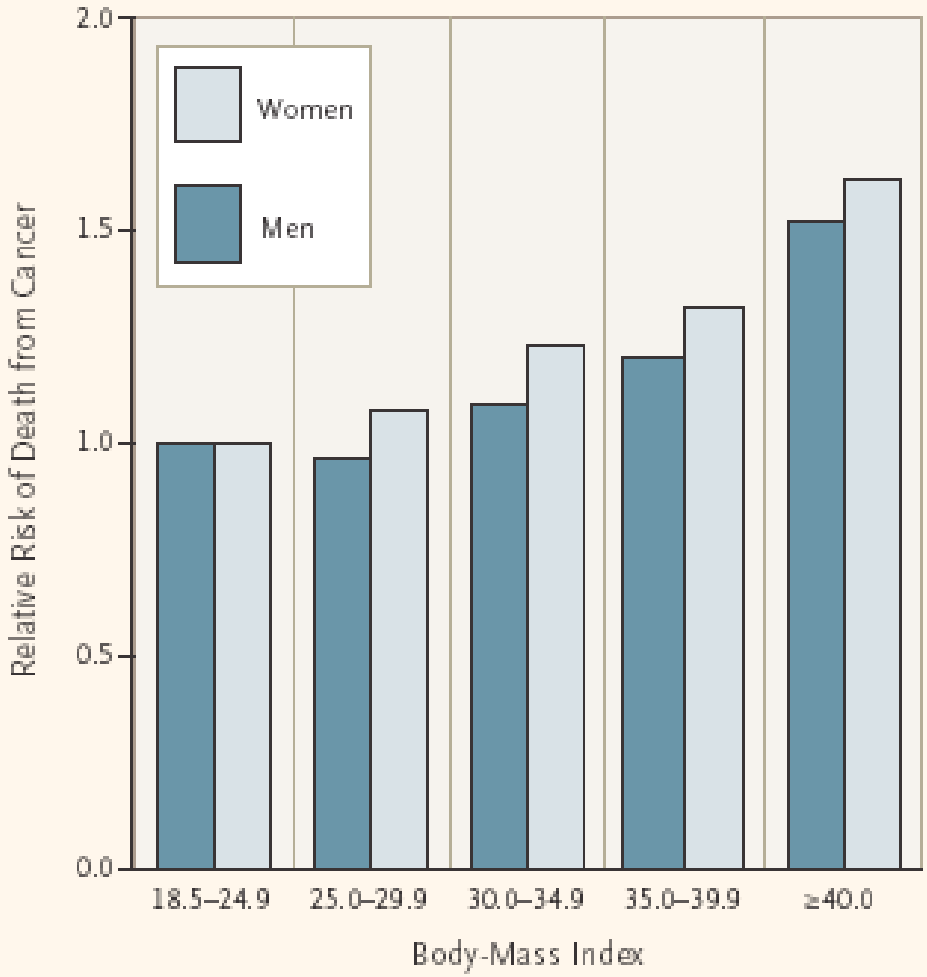
Figure 25-2 Relationship of body mass index and the risk of death from all causes.
SOURCE: Bray and Gray, 1988.

Actual Causes of Death in the United States, 1990*



*Numbers approximated from various studies that used different approaches to derive estimates.

Source: McGinnis JM, Foege WH. Actual causes of death in the United States. *JAMA* 1993; 270(18):2207–12.



Contribution of Overweight and Obesity to Mortality from Cancer in the United States.

Data are from the Cancer Prevention Study II, 1982 through 1998.

Calle et al. NEJM 348:1625-1638, 2003.

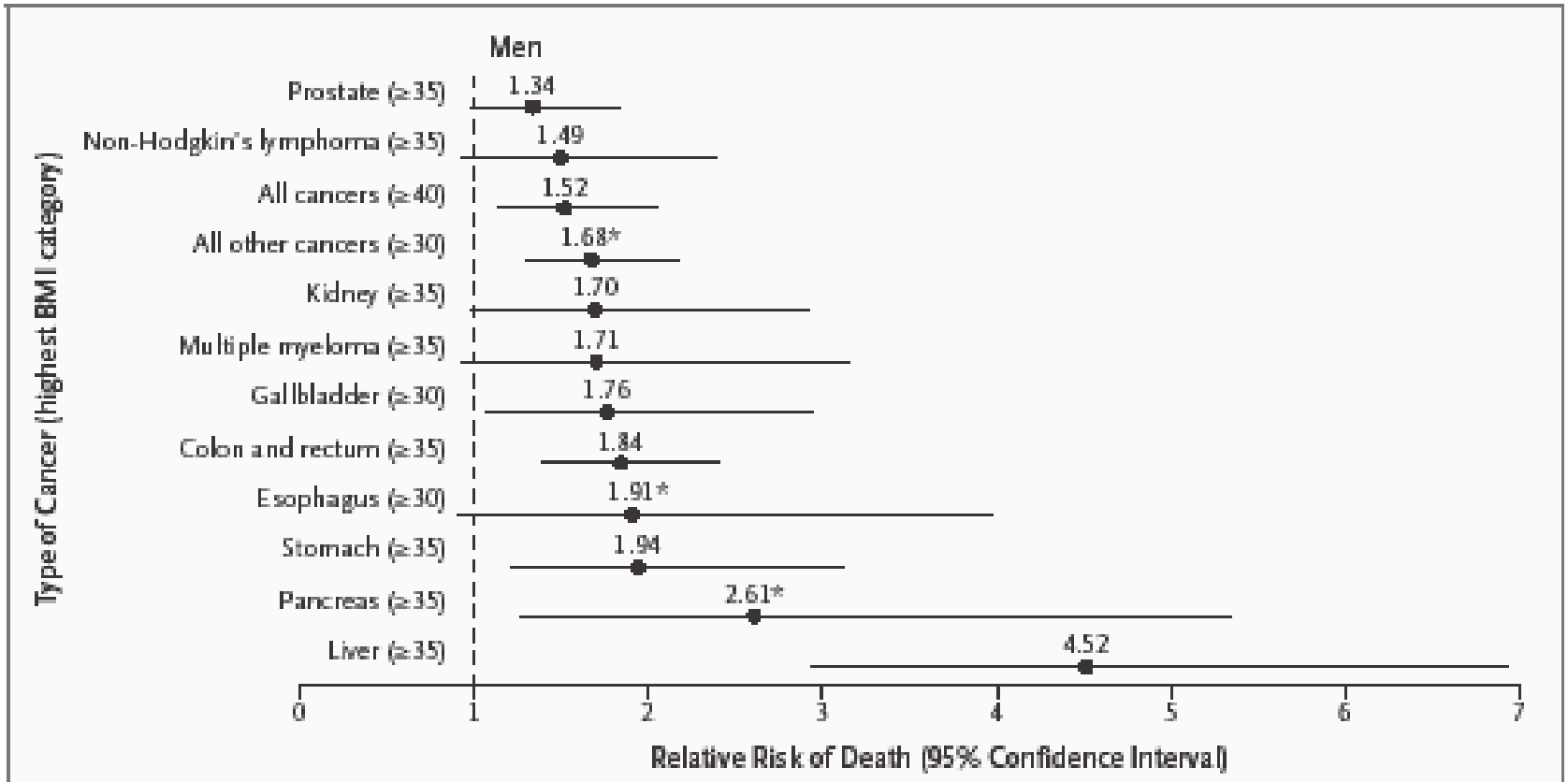


Figure 1. Summary of Mortality from Cancer According to Body-Mass Index for U.S. Men in the Cancer Prevention Study II, 1982 through 1998.

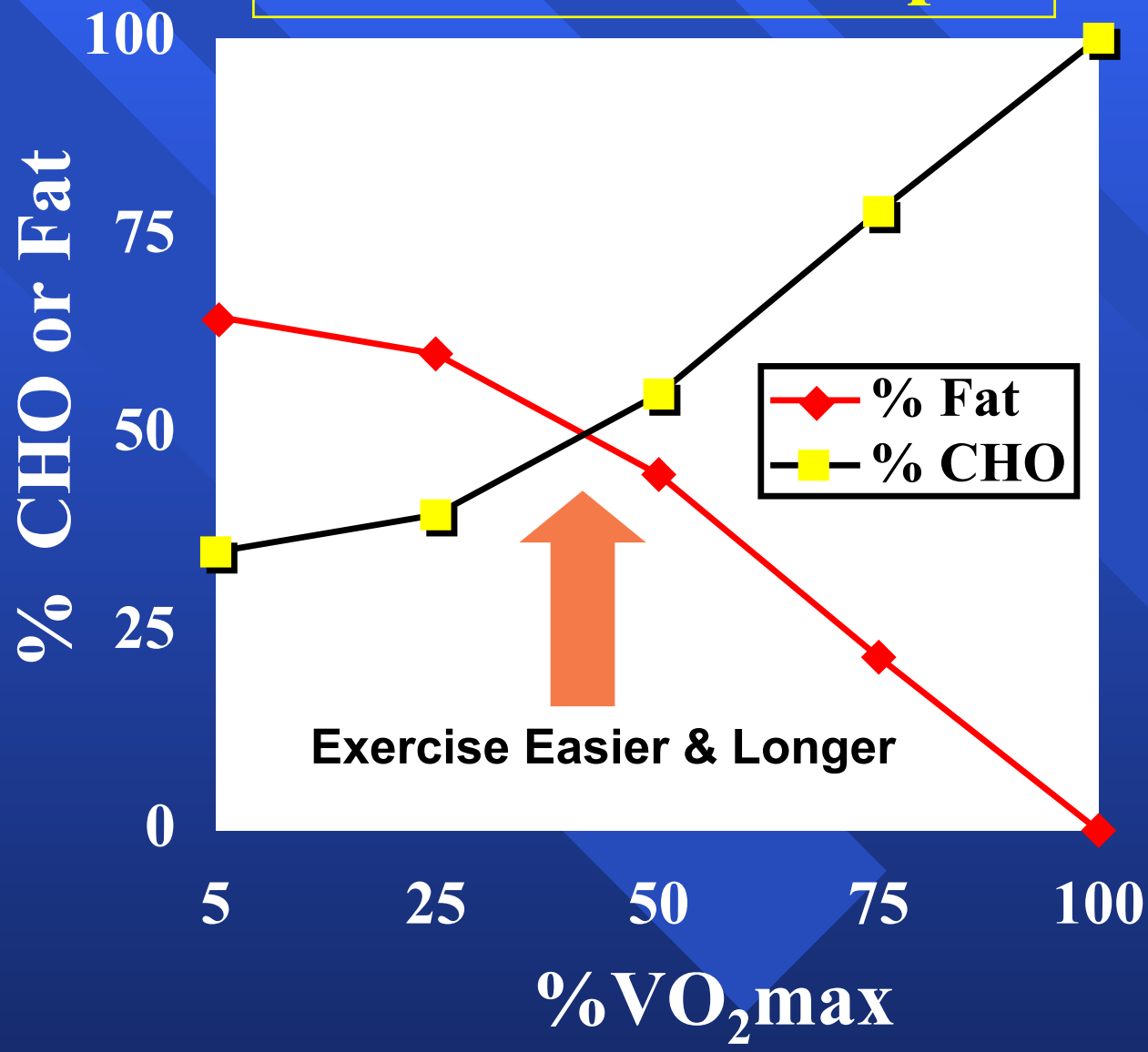
For each relative risk, the comparison was between men in the highest body-mass-index (BMI) category (indicated in parentheses) and men in the reference category (body-mass index, 18.5 to 24.9). Asterisks indicate relative risks for men who never smoked. Results of the linear test for trend were significant ($P \leq 0.05$) for all cancer sites.

Calle et al. NEJM 348:1625-1638, 2003.

Crossover Concept

- Exercise prescriptions to oxidize body fat need consider the Crossover Concept
- At exercise intensities eliciting greater than 45-50% VO_2max, the body fuel selection switches, crossover from, preponderance of lipid to mainly carbohydrate (glycogen, glucose, lactate).

Crossover Concept



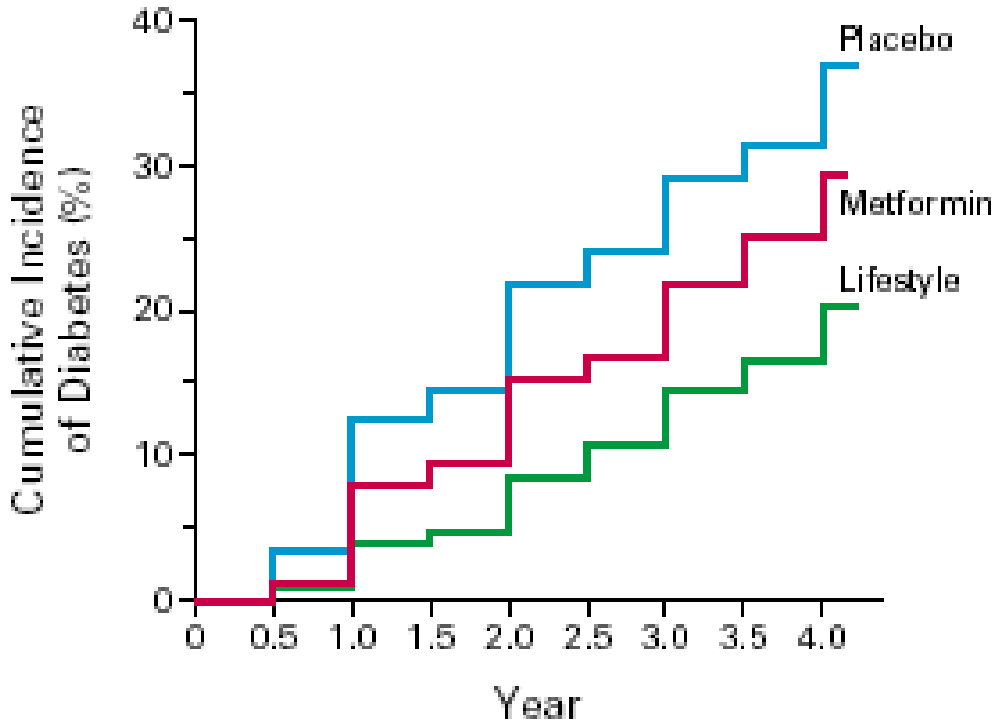


Figure 2. Cumulative Incidence of Diabetes According to Study Group.

The diagnosis of diabetes was based on the criteria of the American Diabetes Association.[11] The incidence of diabetes differed significantly among the three groups ($P<0.001$ for each comparison).

From: NEJM 346(6), 2002

Exercise Recommendation

- If you like the lecture,

- **Take a Hike.**

Exercise Recommendation

- If you don’t like the lecture

Exercise Recommendation

- If you don't like the lecture,

- **Take a Hike.**

Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

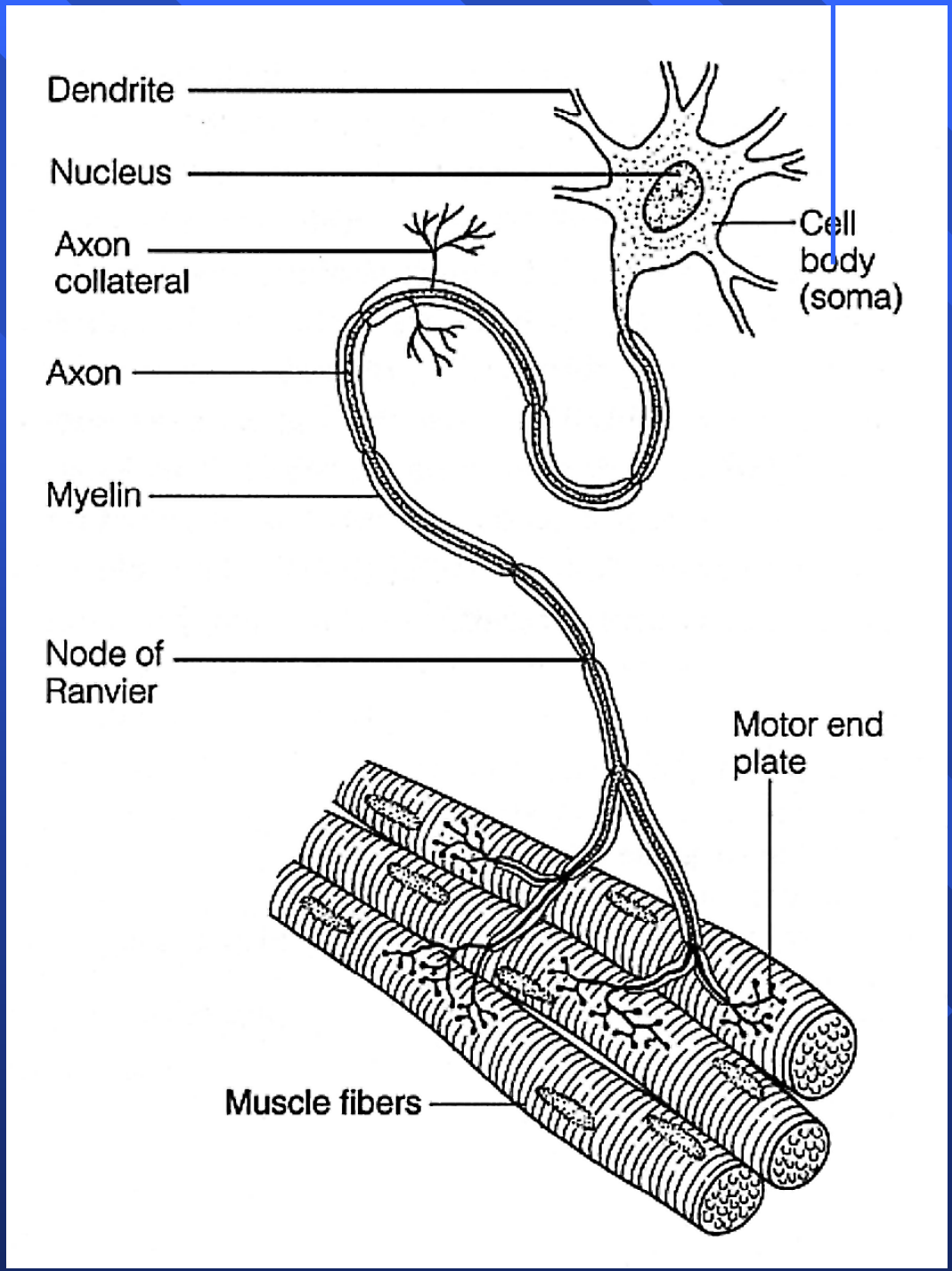


Figure 18-5 A motor unit, consisting of a cell body, the outgrowing α motoneuron, and all of the muscle fibers it innervates. In this drawing, only two fibers are shown; in reality the number of muscle cells in a single motor unit ranges from several hundred to several thousand.

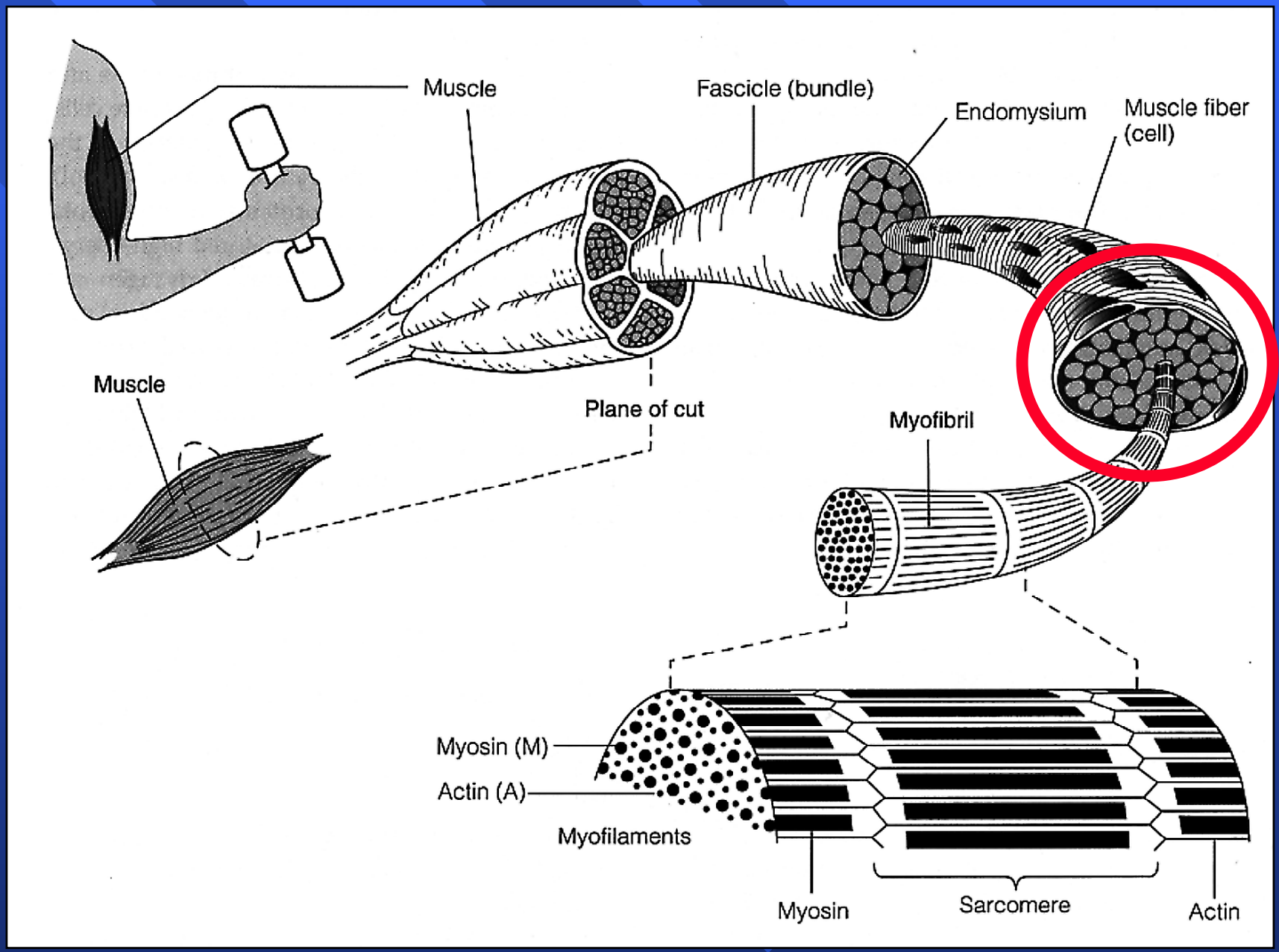


Figure 17-1 Muscle tissue is composed of muscle bundles (fascicles), muscle fibers (cells), myofibrils, and myofilaments (actin and myosin). From Edington and Edgerton

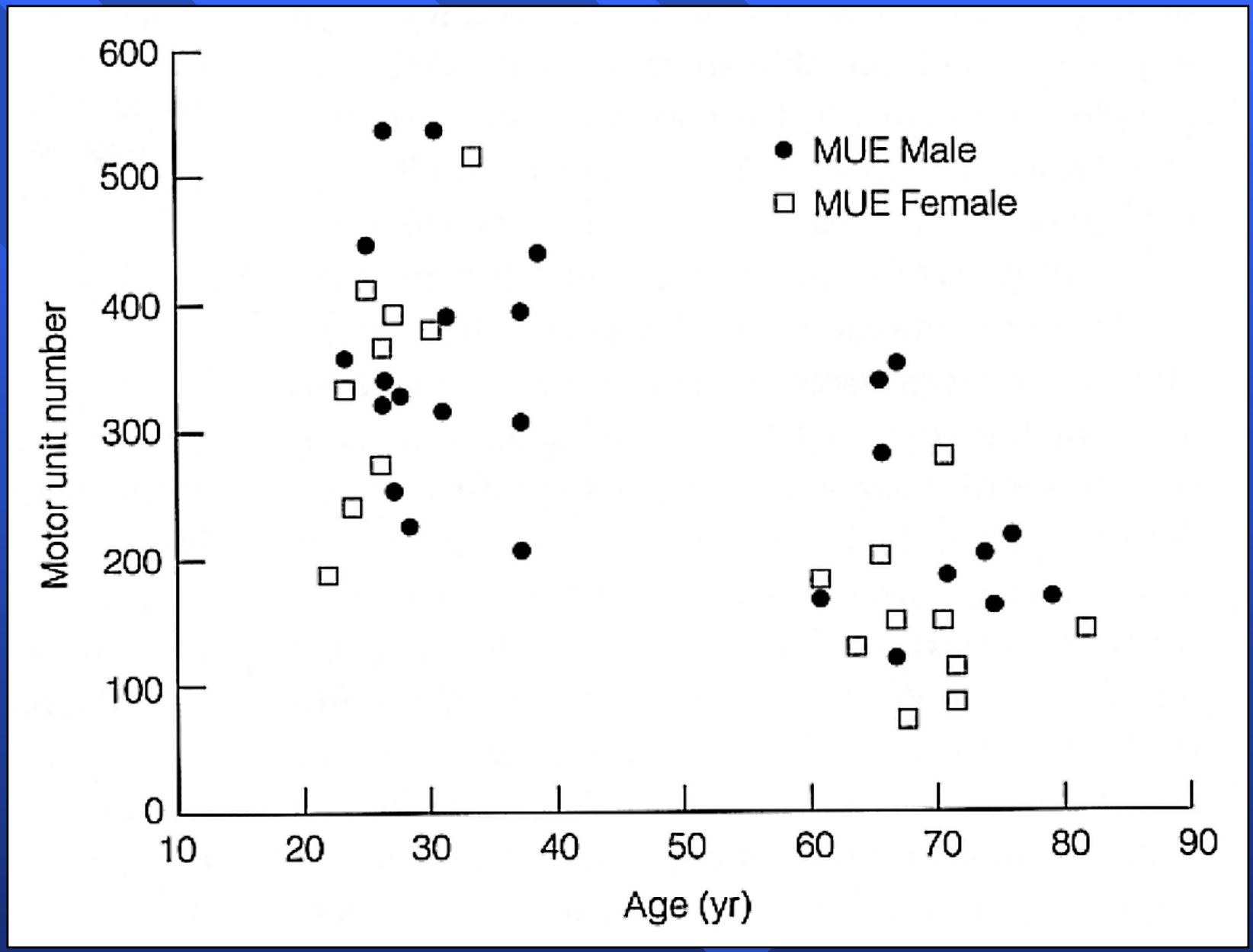


Figure 19-8 Relationship between number of motor units (MUs) and age in young and older men and women. There was a significant reduction in numbers of MUs with age ($P < 0.001$). Adapted from Doherty et al., 1993.

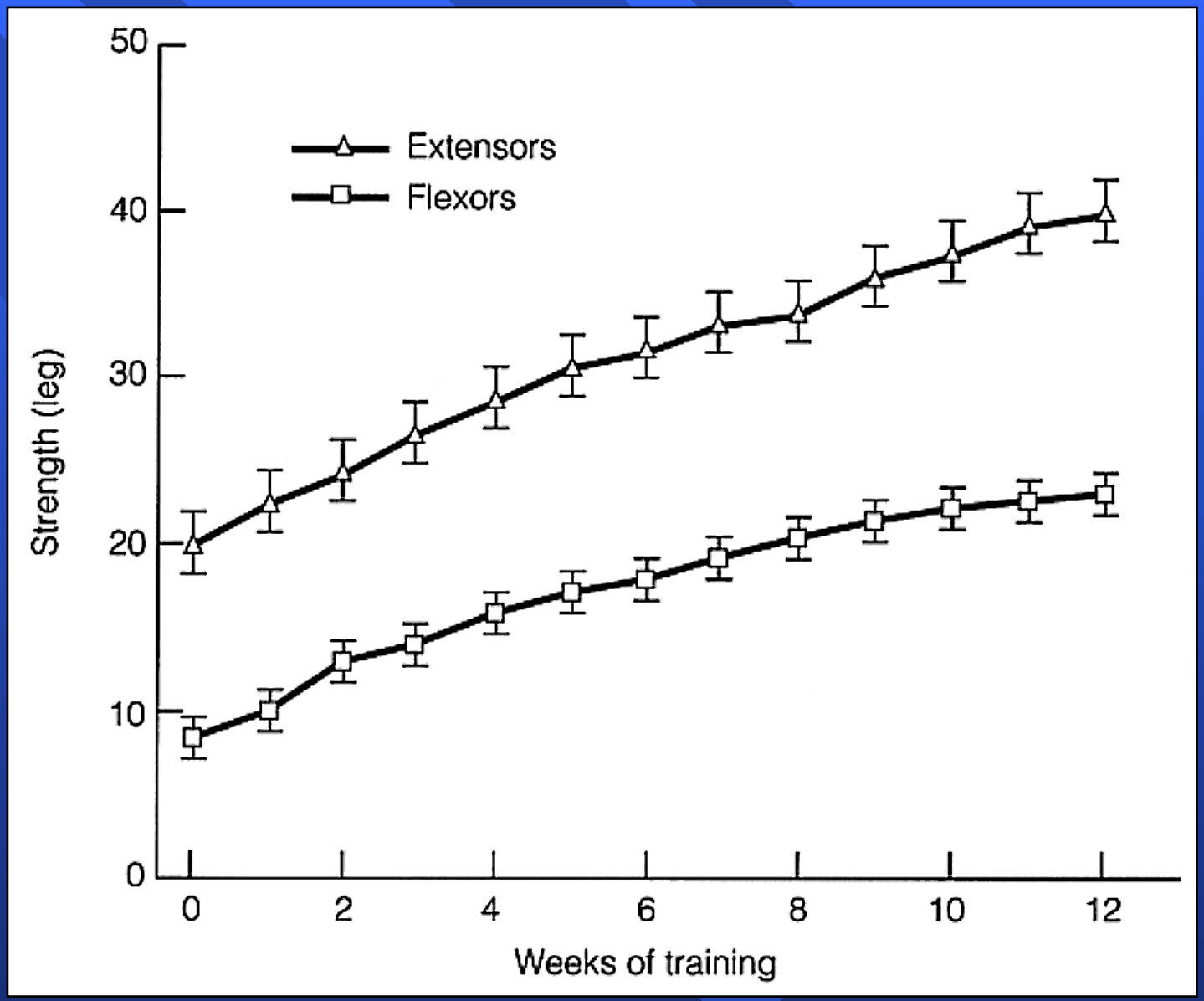


Figure 19-11 Weekly measurements of dynamic muscle strength (1-repetition maximum) of left knee extensors and flexors. Results are means ± SE. From Frontera et al., 1988. Used with permission.

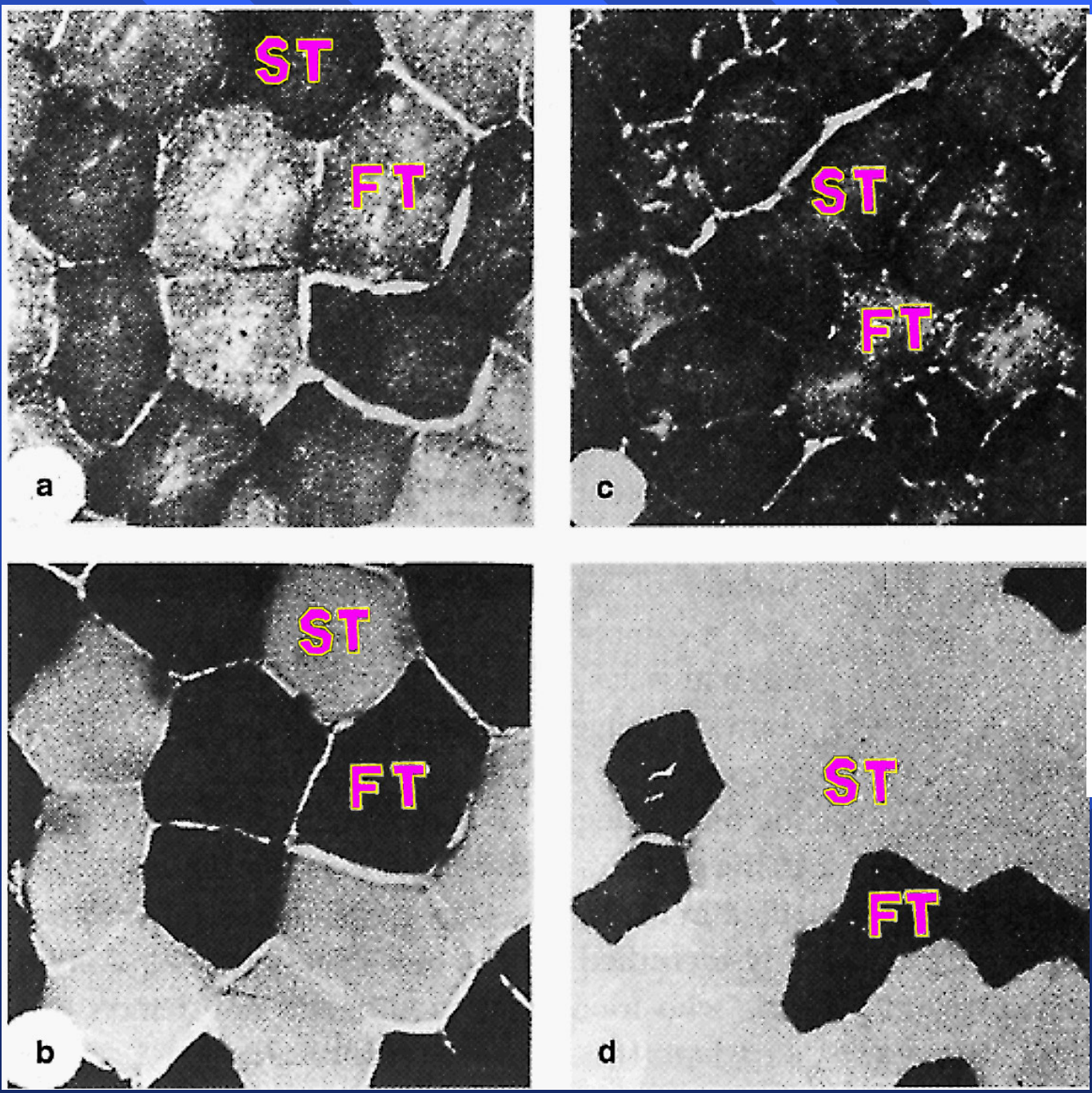


Figure 19-2 Serial sections of quadriceps muscle from two different athletes, stained with two different stains: (a) and (b) from an outstanding sprinter, (c) and (d) from an outstanding distance runner. Sections (a) and (c) are stained for succinic dehydrogenase (SDHase); (b) and (d) stained for alkaline myofibrillar-ATPase stain (M-ATPase). Note that fast fibers, which stain dark with M-ATPase, often are pale and stain weakly with SDHase. FT = fast-twitch fibers; ST = slow-twitch fibers. Note the two dark FT fibers in (d), which also stain dark for SDHase in (c). These are FOG fibers (see Figure 18-15). SOURCE: Gollnick, et al., 1972. Used with permission.

ST, Type I
FT, Type II

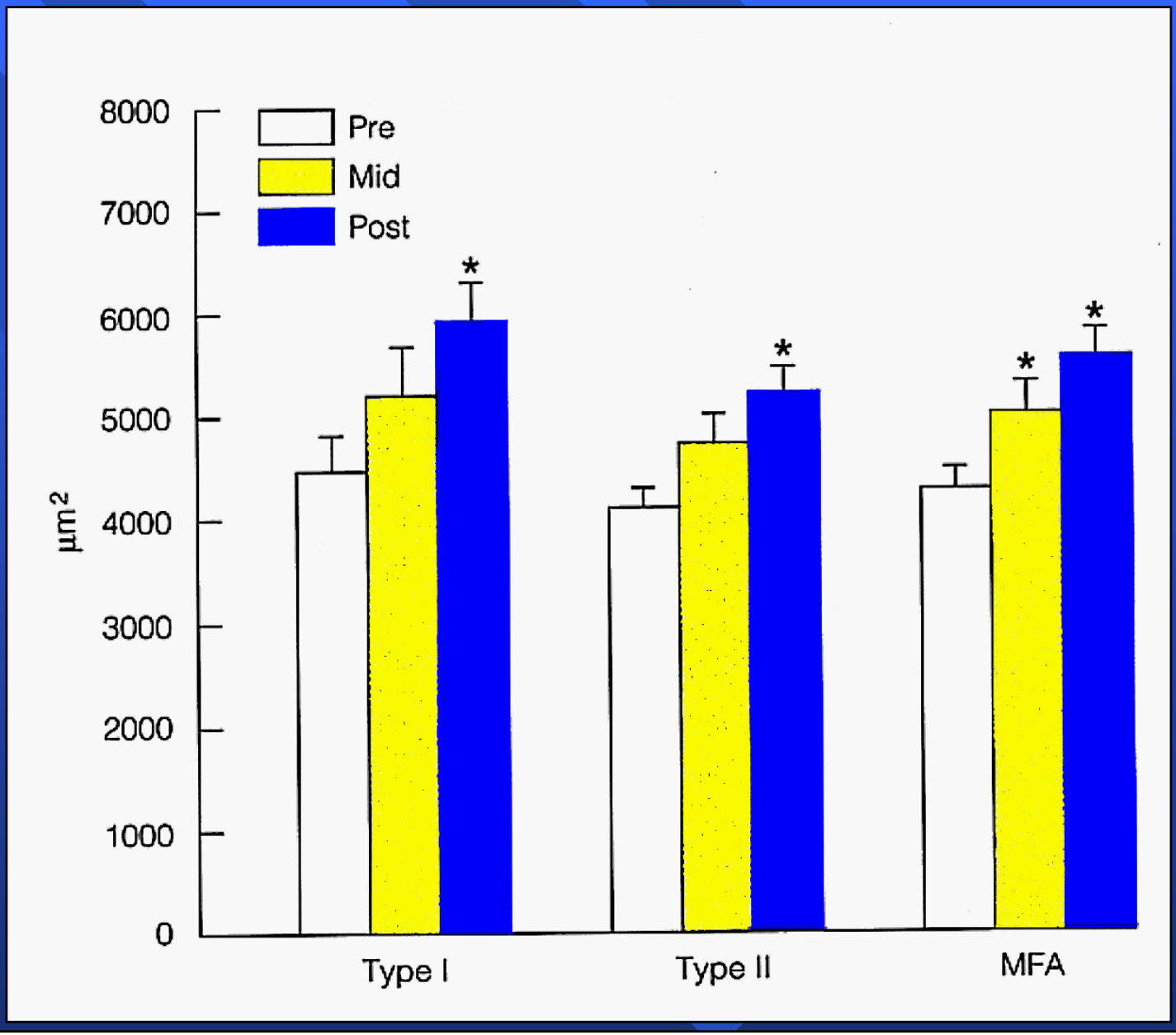
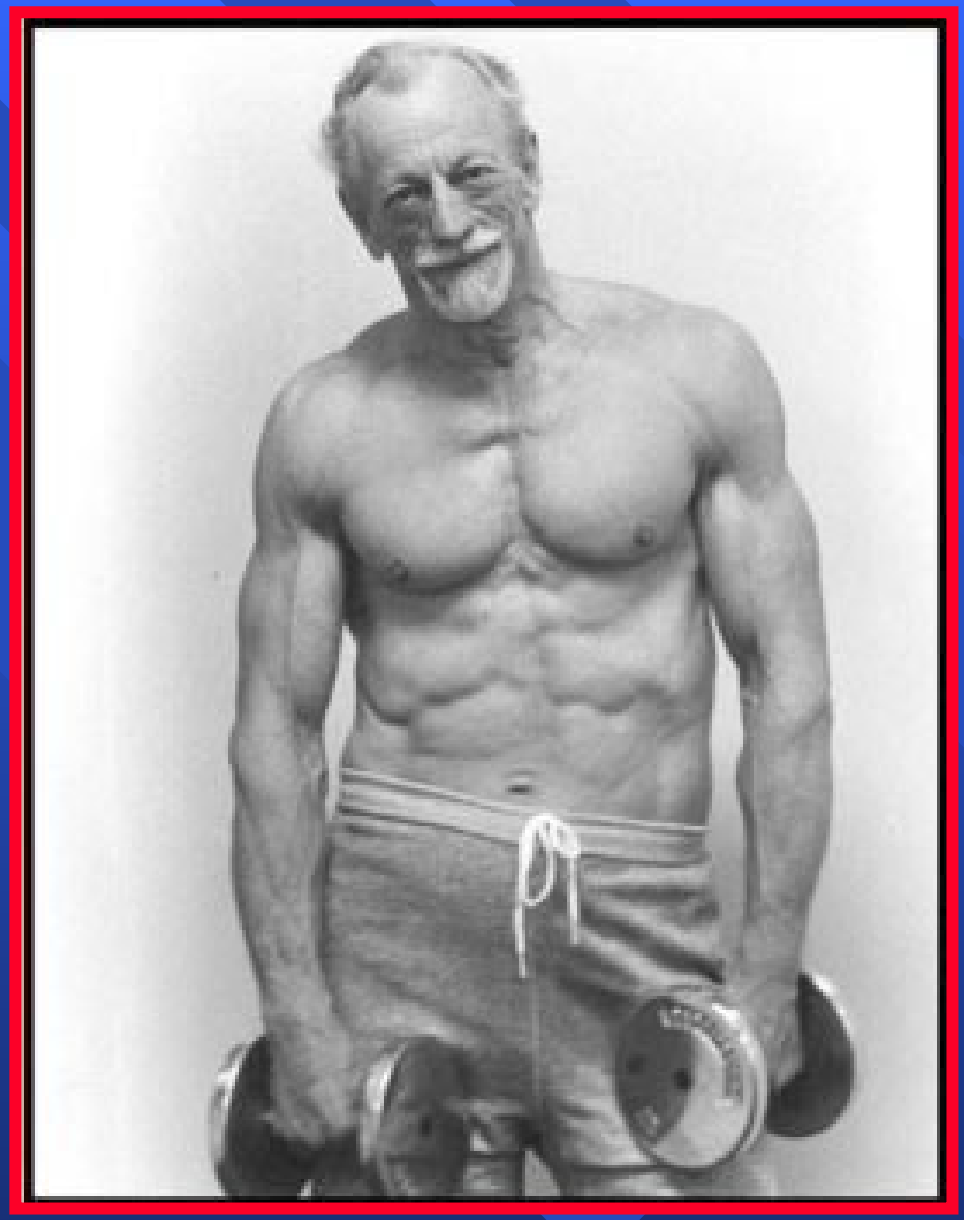


Figure 19-13 Effects of strength training on the area of type I and type II fibers of vastus lateralis muscle of the left leg. Results are means ± SE. * Different from pretraining measurements ($P < 0.05$). SOURCE: Frontera et al., 1988. Used with permission.



John Turner:Age 67

Helen Zechmeister, Age 81

Source: W. Evans

Professor Paola Timiras, 21+

Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

Muscular-Skeletal Strength, Flexibility & Health

- Muscle Strength Can Increase In the Aged
- Exercise Has a Role in Developing and Maintaining the "Bone Bank"
- Increased Strength and Coordination Can Help Prevent Falls and Consequent Injuries

OSTEOPOROSIS

Annual Incidence of Common Diseases In Women

Osteoporotic Fractures	**> 1,000,000**
Heart Attack	513, 000
Stroke	228,000
Breast Cancer	182,000
Uterine Cancer	32,000
Ovarian Cancer	26,000
Cervical Cancer	15,800

Source: CDC & W. Evans

OSTEOPOROSIS

Associated with 1.3 Million Fractures Each Year

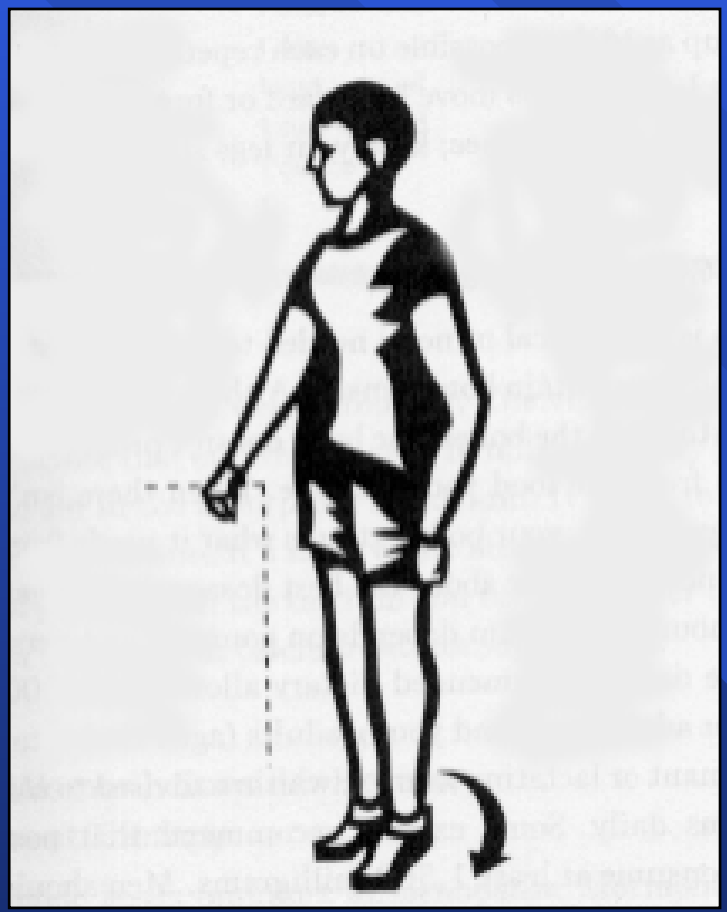
> 250,000 hip fractures

>240,000 wrist fractures

> 500,000 spinal fractures

Source: CDC & W. Evans

Stress and Bone Density



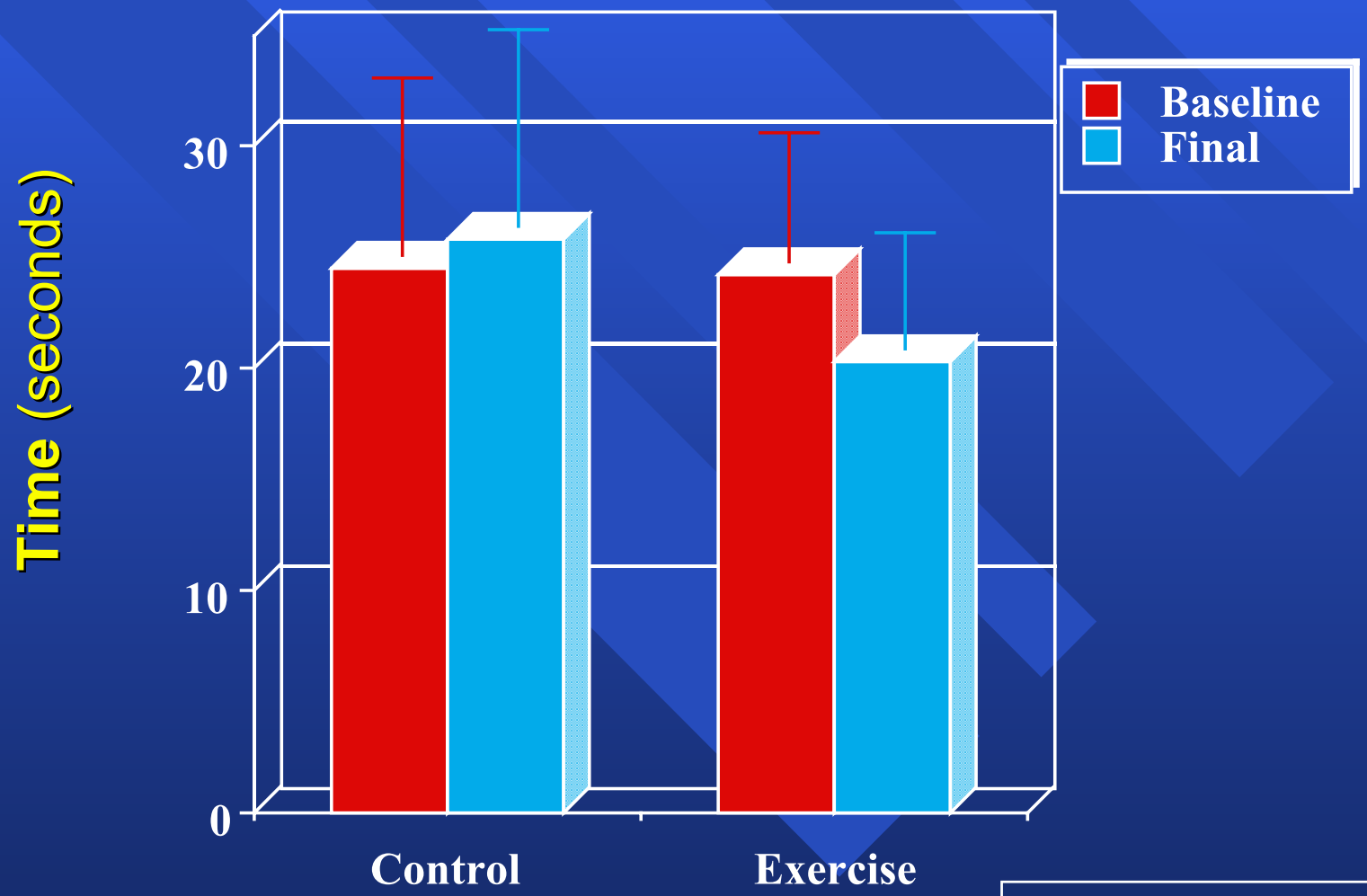
- 3 - 4% increase in bone density in 6 months
- 50 heel drops per day

Bassey, E. J., Increase in femoral bone density in young women following high-impact exercise, Osteoporosis International 1994 4:72-75

Source: W. Evans

Effects of strength training on balance:

Backward Tandem Walk Time



Source: W. Evans

Freedom From Injury

- Freedom From Injury = Freedom of Movement

Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

Antioxidant Defenses

- Regular Physical Exercise Helps to Increase or Maintain Control Age -Related Decreases in Muscle Mitochondrial Mass and Antioxidant Defenses
- Training can result in **100% Increments** in Mitochondrial Mass, Oxidative (Respiratory Enzymes) and Related Enzymes for Defense Against Oxygen-Free Radicals

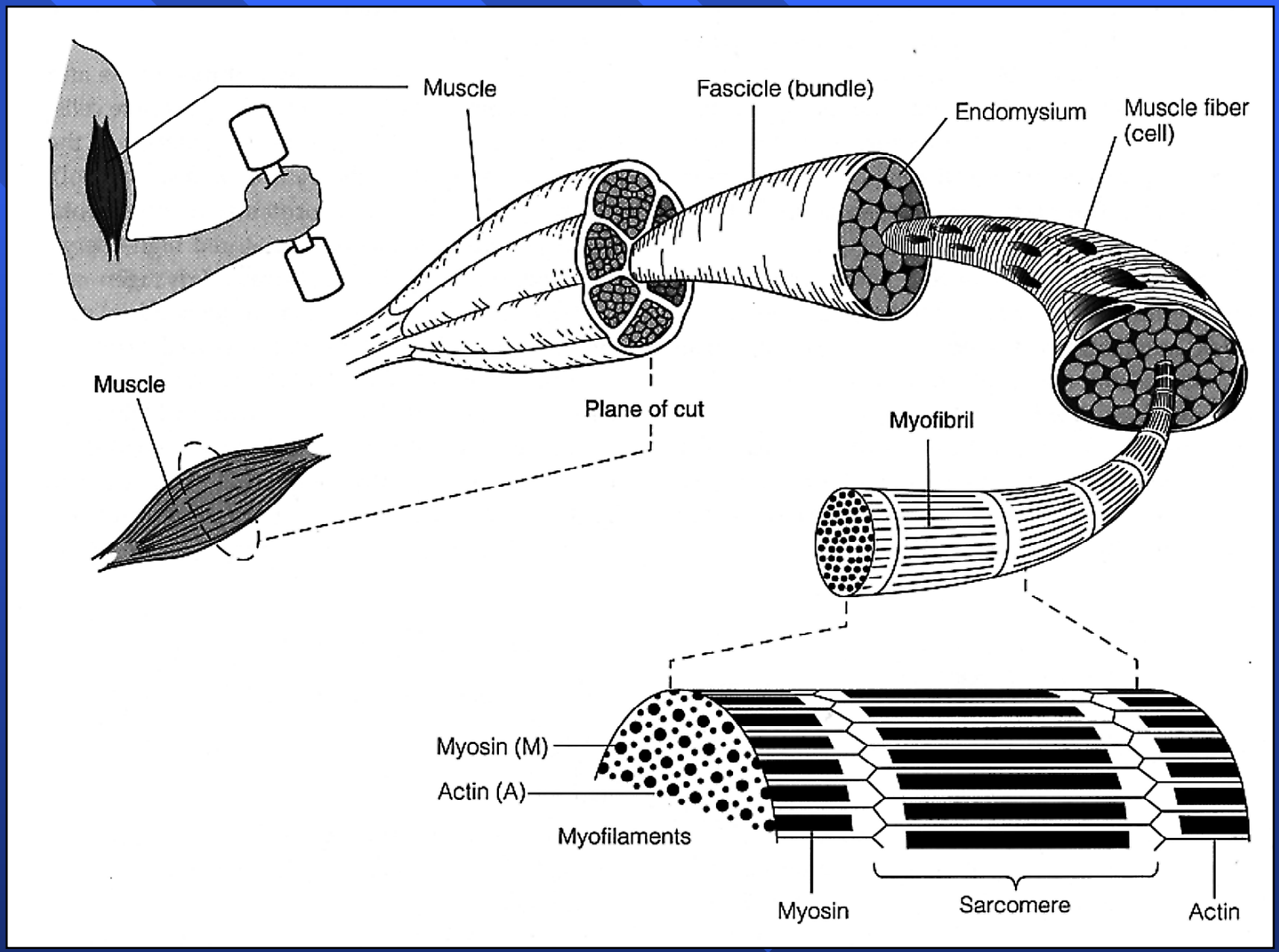


Figure 17-1 Muscle tissue is composed of muscle bundles (fascicles), muscle fibers (cells), myofibrils, and myofilaments (actin and myosin). From Edington and Edgerton

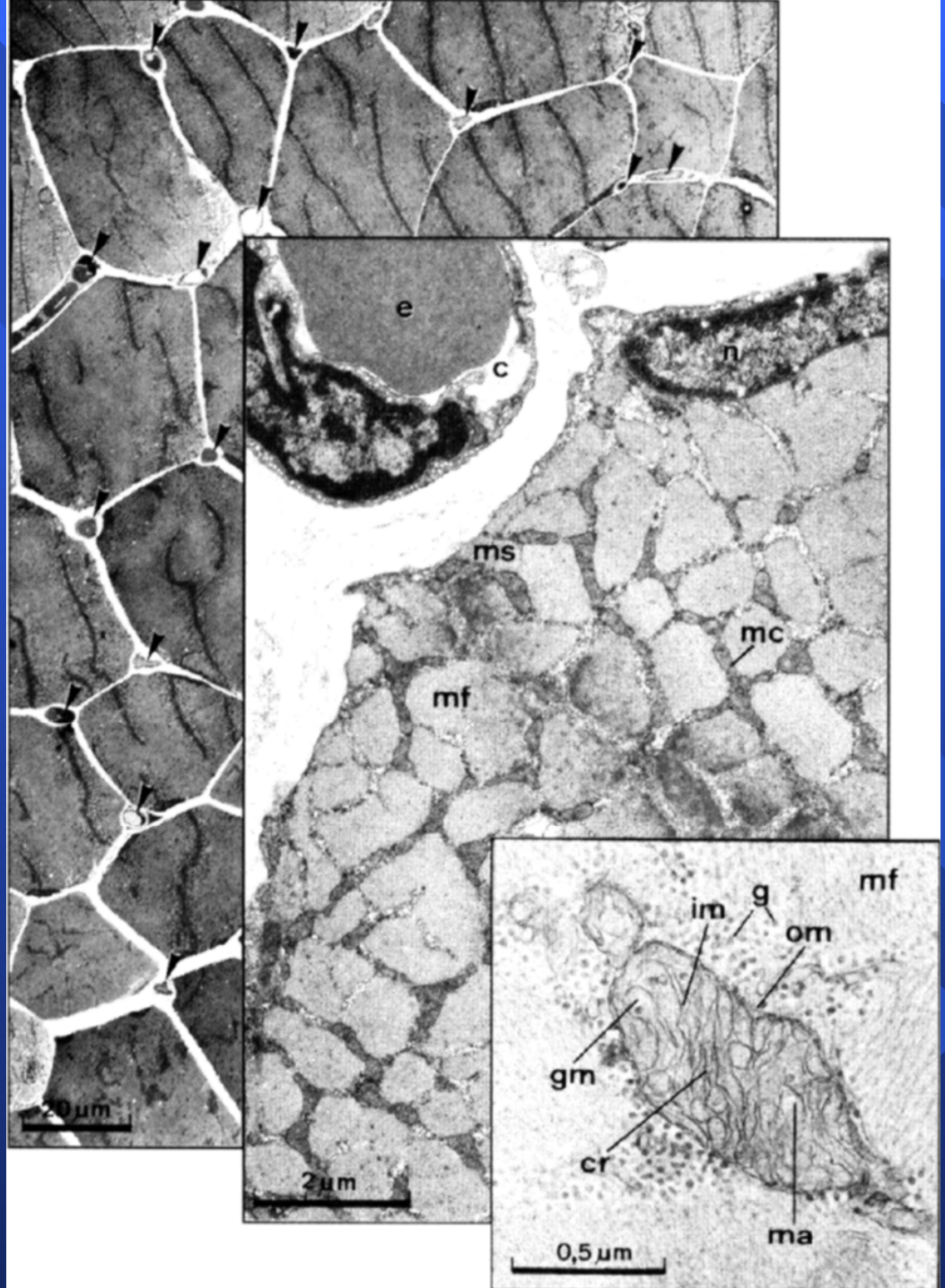


Figure 6-3 Cross sections of human skeletal muscle tissue illustrating the sampling design used for analyzing muscle respiratory structures. The low-level magnification is used for assessing capillarity and fiber size. The intermediate magnification allows for estimating the volume density of mitochondria and other sarcoplasmic components. The highest magnification allows measurement of mitochondria compartmental spaces and membrane surface areas (arrows = capillaries; c= capillary; e = erythrocyte; mc = central mitochondria; mf = myofibrils; cr = cristae; g = glycogen; gm = mitochondrial granule; ma = matrix; im = intermembrane space; om = outer mitochondrial membrane.
SOURCE: Hoppeler, 1986. Used with permission.

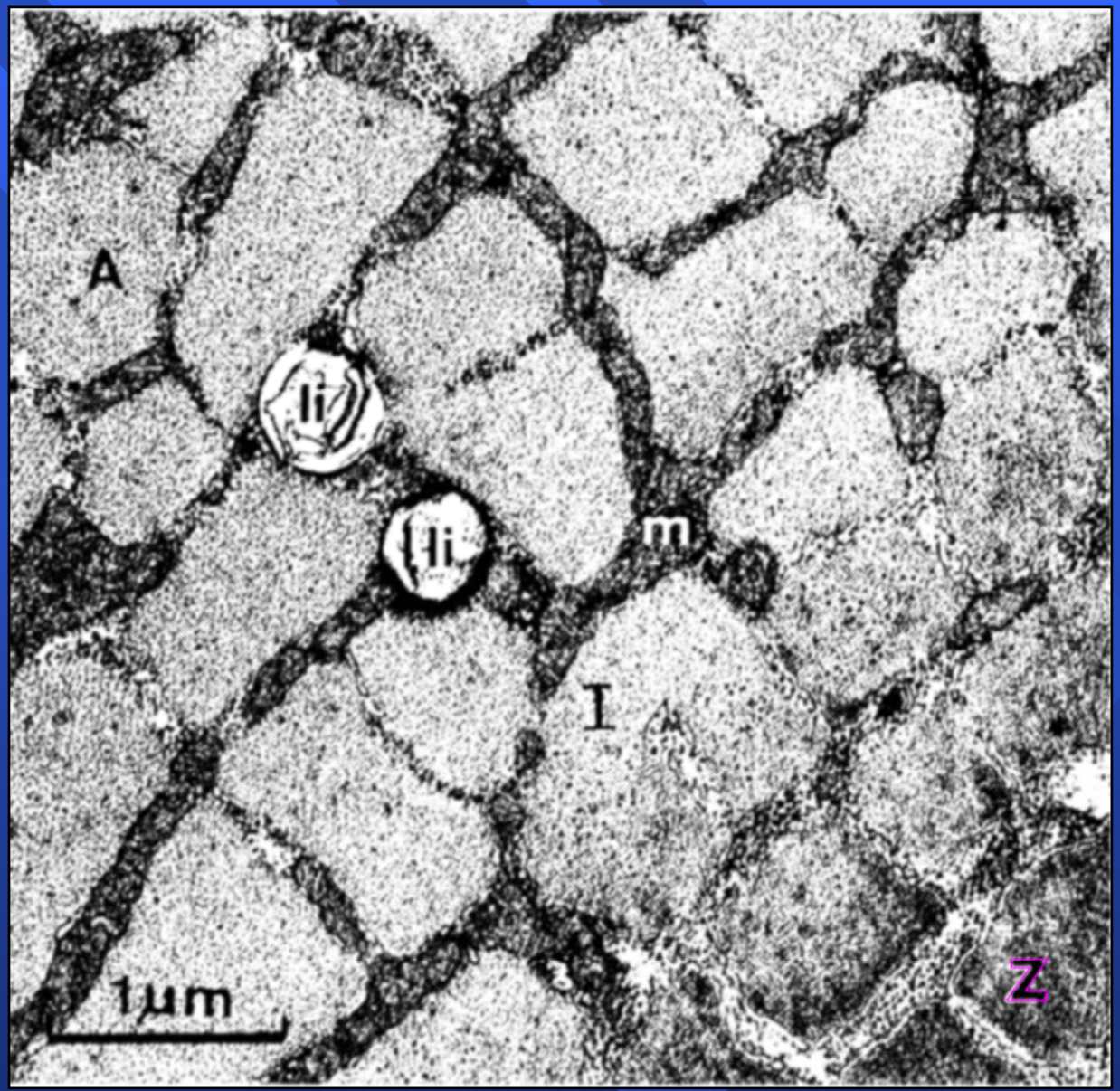


Figure 6-4 Cross section of a portion of a human muscle fiber exposing the A-and I-band and the Z-line regions. Lipid droplets (li) are seen in contact with mitochondria (m). It is evident that the mitochondria in this muscle fiber form an extensively branched tubular network, or reticulum. SOURCE: Hoppeler, 1986. Used with permission.

Metabolic Fitness & Health

- Regular Physical Exercise Helps to Control Age -Related Decreases in Lean Body (Muscle) Mass
- Regular Physical Exercise Helps to Increase or Maintain Control Age -Related Decreases in Muscle Mitochondrial Mass and Antioxidant Defenses

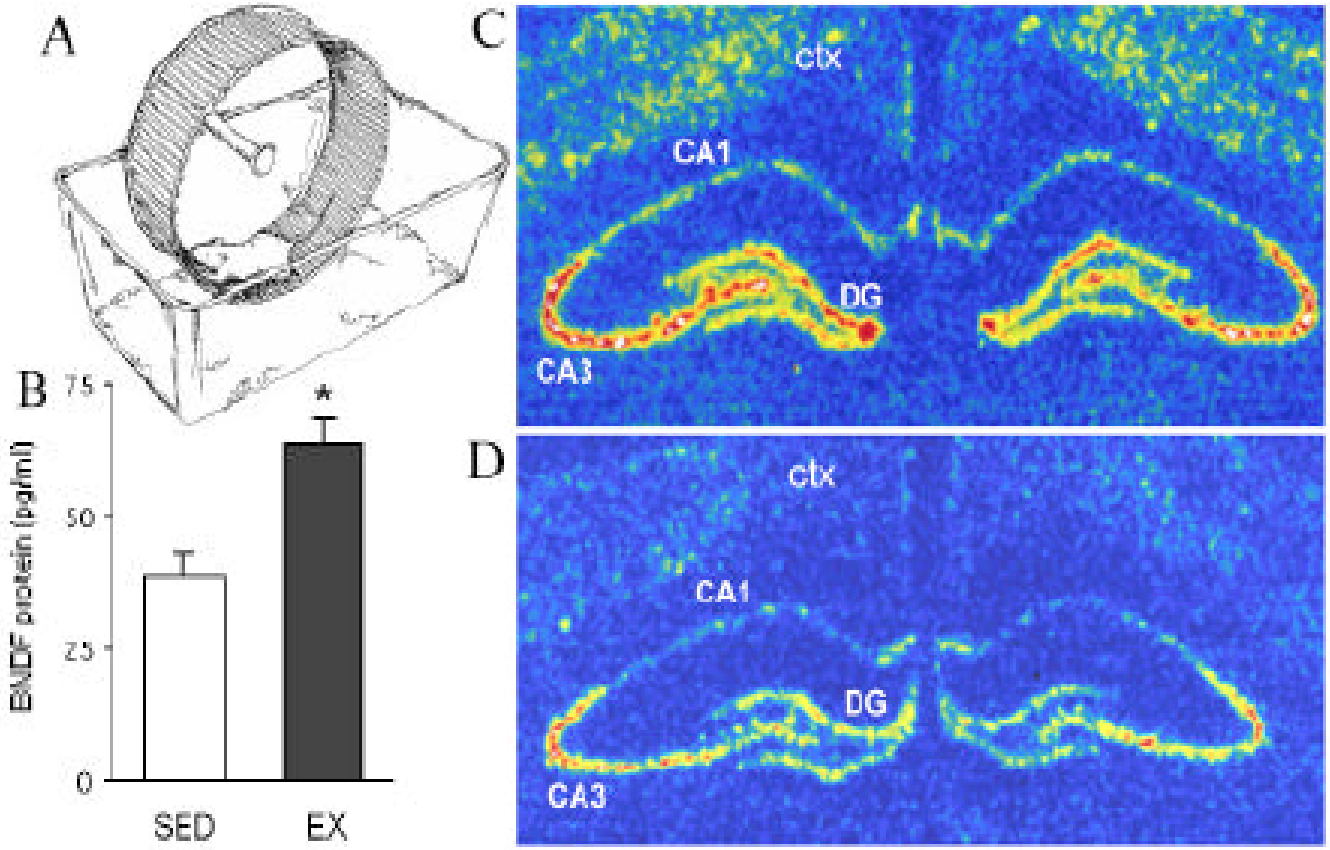
Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

Sense of Well Being

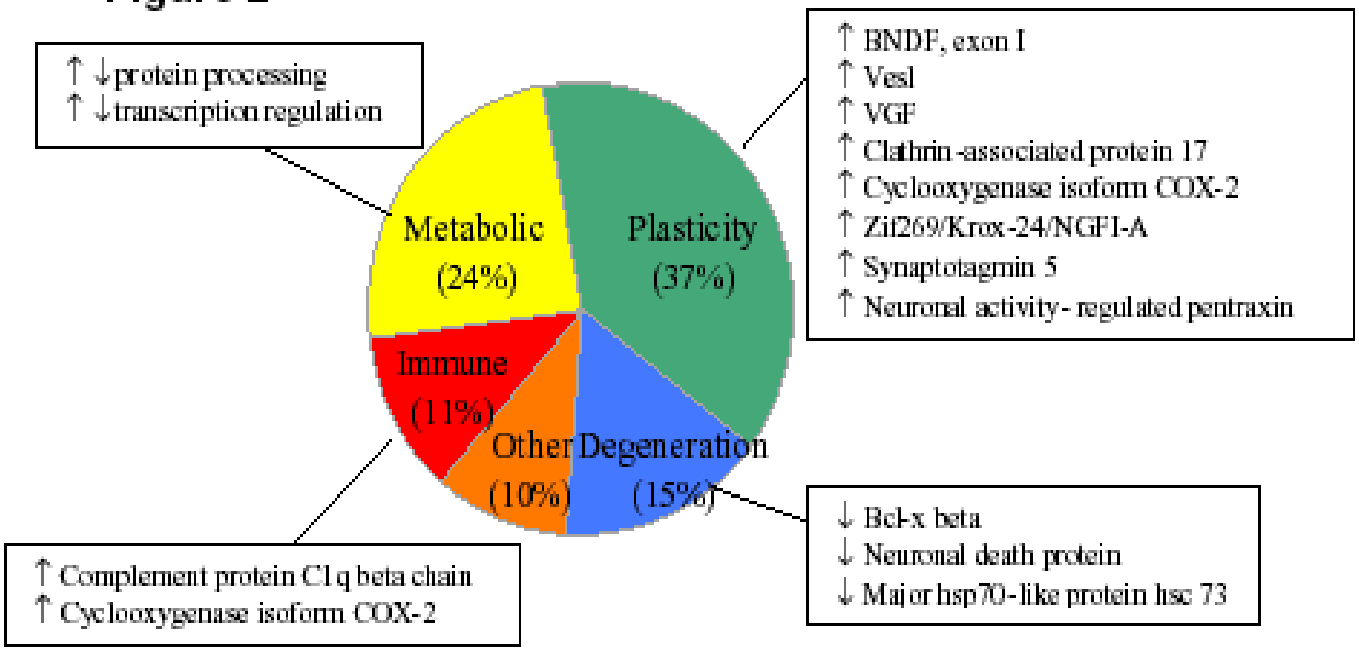
- Physical Exercise Improves Mood
- Physical Exercise May Promote Increases in Levels of Brain-Derived Neurotrophic Factor (BDNF) and other Growth Factors (IGF & FGF).
- BDNF Expression Appears to Increase In Activity- and Cognition-Related Areas such as the Hippocampus.

Figure 1



From: Carl W. Cotman & Nicole C. Bechtold, UC, Irvine
Trends In Neurosci. 25: 295-301, 2002.

Figure 2



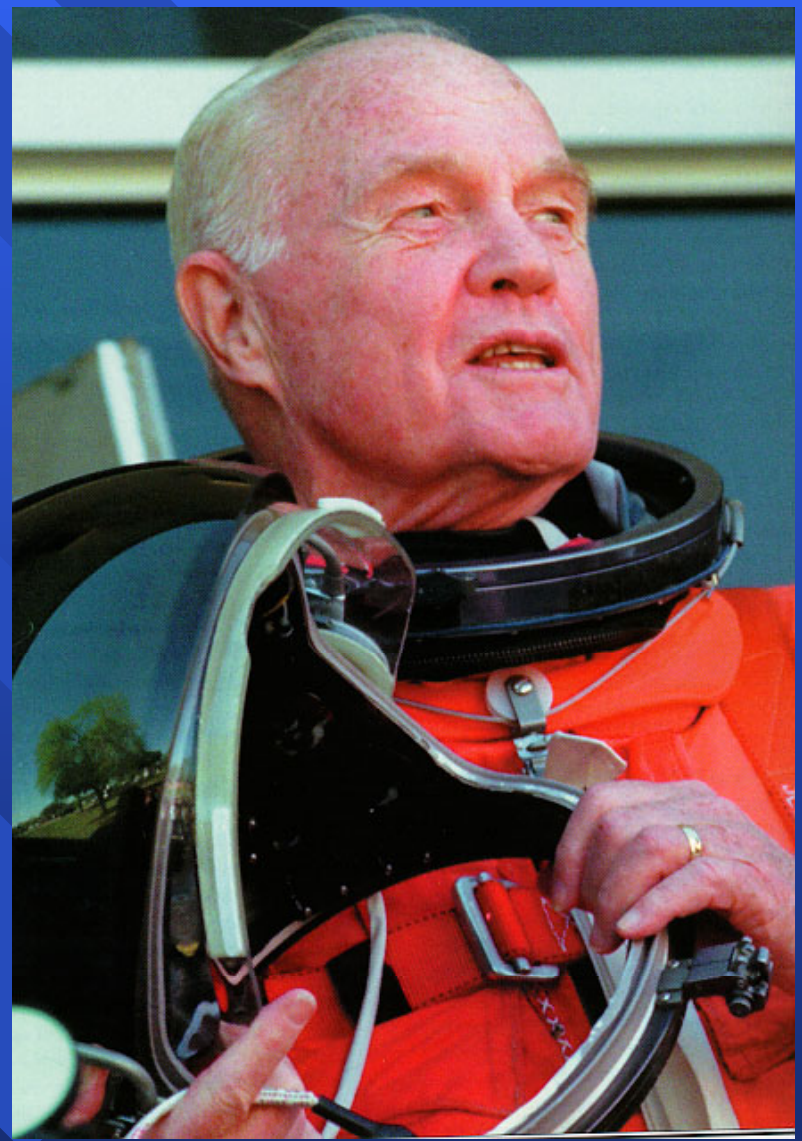
From: Carl W. Cotman & Nicole C. Bechtold, Institute for Brain Aging and Dementia and Department of Neurology, UC, Irvine

Why Exercise?

- Cardiovascular Fitness & Health
- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
- Antioxidant Defenses
- Sense of Well Being

Though I look old, yet I am strong and lusty;
For in my youth I never did apply
Hot and rebellious liquors in my blood
Nor did not with unbashful forehead woo
The means of weakness and debility;
Therefore my age is as a lusty winter,
Frosty, but kindly. Let me go with you;
I'll do the service of a younger man
In all your business and necessities.

William Shakespeare, *As you like it*, Act II, Scene III, lines 46-55



Why Exercise?

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- Metabolic Fitness & Health
- Muscular-Skeletal Strength, Flexibility & Health
- Freedom From Injury
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Exercise Recommendation

Take a Hike.