SPINE AND HOLISTIC HEALTH · STUDY GUIDE

Final Review Study Guide

The final covers all fourteen chapters. Each chapter here is shorter than in the study guides: three paragraphs of what to know, the chapter diagram, the points to lock in, one table, two worked cases, the main traps and six new board style self-test items. If a chapter feels shaky, go back to its study guide for the full treatment. The long cram sheet at the end gathers every number, formula and rule from the course into one place. Work two chapters a day and the whole course fits into a week.

WHAT THIS GUIDE COVERS

- Structure and motion: chapters 1 and 2 (the spine in three dimensions; spinal biomechanics).
- Joints and hands on care: chapters 3 and 4 (joints, cavitation and healing; manipulation and mobilization mechanics).
- Nerves and pain: chapters 5 and 6 (nerve roots, dermatomes and reflexes; pain neuroscience).
- Examination and movement: chapters 7 and 8 (exam logic and red flags; posture, gait and movement).
- History and context: chapters 9 and 10 (chiropractic models through history; the transformation of American medicine).
- Evidence and physiology: chapters 11 and 12 (reading the evidence; stress and the autonomic nervous system).
- Holistic practices: chapters 13 and 14 (breathing, meditation and yoga; traditional systems and nature therapy).
- Every chapter carries what to know, a labeled diagram, a table, two worked cases, the traps and a six item self-test, and the cram sheet holds everything else.

CHAPTER 1

The Spine in Three Dimensions

Read it in full: **Chapter 1 in the textbook**. See it in motion: **Spine in Three Dimensions** and **Spine Lab**.

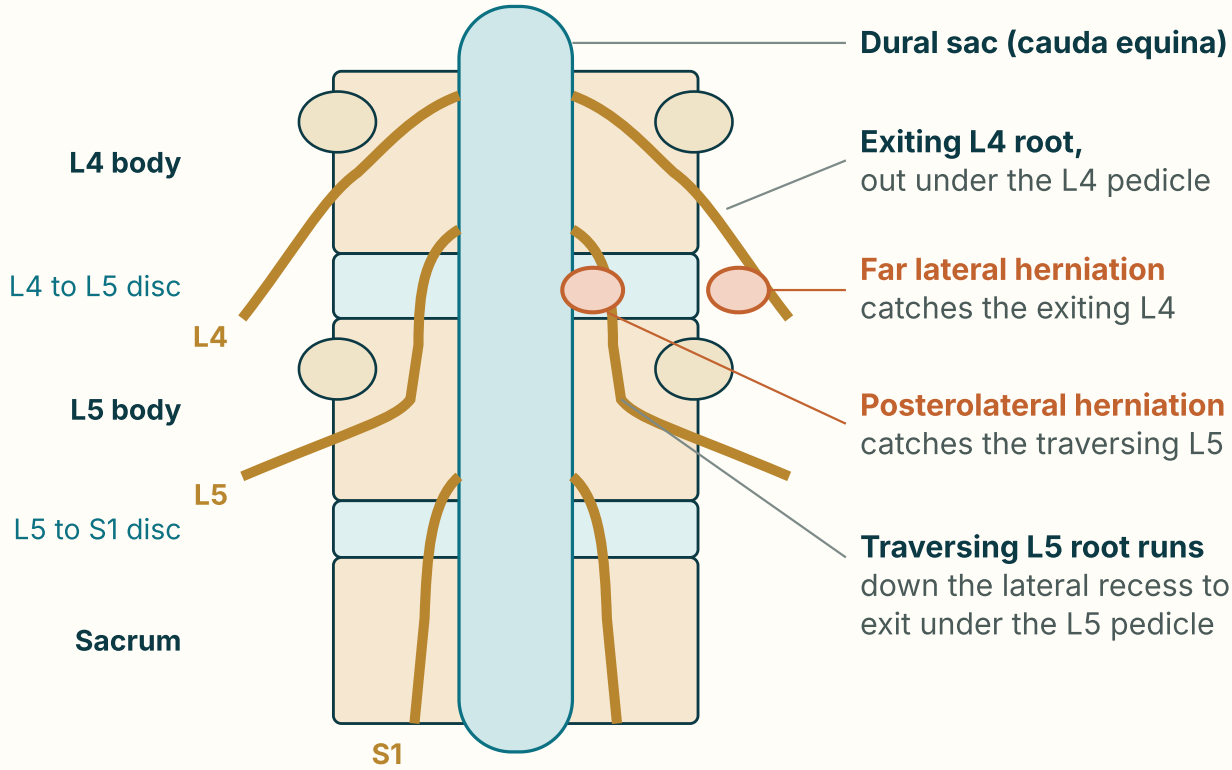
What to know

The adult column has 7 cervical, 12 thoracic and 5 lumbar vertebrae above a fused sacrum (5) and coccyx (usually 4); transitional segments such as sacralization and lumbarization can cause levels

to be miscounted. The thoracic and sacral kyphoses are primary curves; the cervical and lumbar lordoses are secondary, formed with head control and then standing.

The motion segment is two vertebrae plus disc, facets and ligaments, a three joint complex that shares load. A transverse foramen means cervical, rib facets mean thoracic, and a large kidney shaped body means lumbar. The disc is a water binding nucleus inside a crisscrossed annulus, fed by diffusion through the endplates. Facets sit at 45 degrees in the neck, near frontal in the thorax and near sagittal in the low back. The ALL limits extension; the structures behind the bodies limit flexion.

Intrinsic back muscles are supplied by dorsal rami. The cord ends near L1 to L2 and the cauda equina fills the canal below; its compression is an emergency. Cervical nerves exit above their vertebra, C8 between C7 and T1, and lower nerves below. A posterolateral L4 to L5 herniation hits the traversing L5 root; a far lateral one hits the exiting L4 root.



Posterior view, laminae removed. Left: normal roots. Right: the two kinds of herniation.

Which root a herniation catches. At the L4 to L5 disc the L4 root has already left under its pedicle, so a posterolateral herniation hits the traversing L5 root and only a far lateral herniation hits the exiting L4 root.

LOCK THESE IN

- Counts: 7 cervical, 12 thoracic, 5 lumbar, 5 fused sacral, usually 4 coccygeal; 33 at birth, about 24 movable above the sacrum.
- Primary curves (present before birth) are the kyphoses: thoracic and sacral. Secondary curves are the lordoses: cervical (head control) and lumbar (standing).
- Motion segment = two vertebrae + disc + two facets + ligaments; three joint complex = one symphysis in front, two synovial facets behind.
- Transverse foramen = cervical; costal facets = thoracic; large kidney shaped body = lumbar. Atlas has no body; the dens belongs to C2.
- 23 discs, the first at C2 to C3. Endplate fails first under pure compression. Inner disc is fed by diffusion; only the outer third of the annulus has nerves.
- ALL limits extension; PLL, flavum, interspinous, supraspinous and capsules limit flexion.
- Intrinsic back muscles: dorsal rami. Superficial and intermediate: ventral rami (trapezius: spinal accessory nerve).
- Conus near L1 to L2, dural sac to S2. Posterolateral L4 to L5 herniation hits L5; far lateral hits L4.

Regions at a glance

Region	Count	Adult curve	Signature features	Facet plane and favored motion
Cervical	7	Lordosis (secondary)	Transverse foramina; bifid spinous C2 to C6; uncinate processes	About 45 degrees; all directions, rotation at C1 to C2
Thoracic	12	Kyphosis (primary)	Costal facets; long downward spinous processes; small round canal	Near frontal; rotation and side bending, limited by ribs
Lumbar	5	Lordosis (secondary)	Large kidney shaped bodies; mammillary and accessory processes	Near sagittal, curved; flexion and extension
Sacral	5 fused	Kyphosis (primary)	Four pairs of foramina; auricular surfaces; hiatus at S5	Load transfer to the pelvis
Coccygeal	3 to 5 (usually 4)	Continues sacral curve	Rudimentary segments	Pelvic floor attachment

Worked cases

CASE 1.1 · NAMING THE ROOT FROM THE DISC LEVEL

An MRI shows a posterolateral disc herniation at L5 to S1 on the right. Which root is most likely compressed? What if the same disc herniated far laterally?

STEP 1 · FIND THE ROOTS AT THAT LEVEL

At the L5 to S1 disc, the L5 root has already turned out under the L5 pedicle into its foramen. The S1 root is still running down the lateral recess.

STEP 2 · PLACE THE HERNIATION

A posterolateral herniation pushes into the lateral recess, just beside the PLL, where the traversing root runs.

STEP 3 · NAME THE ROOT

So the right **S1** root is the likely one. The quick rule: one number lower than the upper vertebra.

STEP 4 · APPLY THE EXCEPTION

A far lateral (foraminal) herniation meets the root that is exiting at that level, so it would compress the right **L5** root.

CHECK IT

The book gives the same pattern one level up: posterolateral L4 to L5 hits L5, far lateral L4 to L5 hits L4.

CASE 1.2 · IDENTIFYING A VERTEBRA IN HAND

A student is handed an isolated bone. It has no transverse foramen. There are small half facets on the sides of the body, and the spinous process slopes steeply downward. Which region is it from, and what motion does that region favor?

STEP 1 · ASK THE FIRST QUESTION

Is there a transverse foramen? No, so it is not cervical.

STEP 2 · ASK THE SECOND QUESTION

Are there facets on the body for ribs? Yes, costal demifacets, so it is **thoracic**.

STEP 3 · CONFIRM WITH OTHER FEATURES

A long, steeply sloping spinous process fits the middle thoracic region, about T5 to T8.

STEP 4 · LINK TO MOTION

Thoracic facets lie near the frontal plane, which favors rotation and lateral flexion, but the rib cage stiffens the region overall.

TRAPS PEOPLE FALL INTO

- **Calling the lordoses primary.** The primary curves are the kyphoses, present before birth. The lordoses are secondary.
- **Putting the dens on the atlas.** The dens rises from C2. Developmentally it is the body of C1, which is why the atlas has no body.
- **Counting a disc between C1 and C2.** There is no disc between the occiput and atlas or between atlas and axis. The first disc is C2 to C3, for 23 in all.
- **Saying the PLL limits extension.** Only the ALL lies in front of the bodies. Everything behind the bodies, including the PLL, limits flexion.
- **Assuming every herniation hits the exiting root.** A posterolateral lumbar herniation hits the traversing root. Only a far lateral one hits the exiting root.

Chapter 1 self-test · six items

1. How many separate movable vertebrae lie above the sacrum in a typical adult?

A. About 33
B. About 24
C. About 29
D. About 26

B. About 24 7 cervical plus 12 thoracic plus 5 lumbar is 24. The 33 count is at birth, before the sacral and coccygeal segments fuse.

2. Which feature identifies a vertebra as thoracic?

A. A short, bifid spinous process
B. A large, kidney shaped body
C. Rib facets on the side of the body
D. A hole in each transverse process

C. Rib facets on the side of the body Costal facets (demifacets) on the body mark the thoracic region. The transverse foramen marks cervical and the kidney shaped body marks lumbar.

3. Which ligament limits extension of the spine?

A. The anterior longitudinal ligament
B. The posterior longitudinal ligament
C. The interspinous ligament
D. The ligamentum flavum

A. The anterior longitudinal ligament A ligament limits the motion that pulls its ends apart. Only the ALL lies in front of the bodies, so only it is stretched by extension.

4. A posterolateral disc herniation at C6 to C7 most often affects which root?

A. C8
B. T1
C. C6
D. C7

D. C7 Cervical roots exit horizontally above the vertebra of the same number, so the C6 to C7 disc sits at the C7 root. The book calls this the most common cervical root level.

5. Which nerve supply belongs to the intrinsic (true) back muscles?

A. The sinuvertebral nerves
B. Dorsal rami of the spinal nerves
C. The spinal accessory nerve
D. Ventral rami of the spinal nerves

B. Dorsal rami of the spinal nerves The splenius, erector spinae, transversospinalis and segmental muscles are supplied by dorsal rami. The extrinsic layers that developed with the limbs get ventral rami.

6. Where does the spinal cord end in most adults?

A. Near the L3 to L4 disc
B. Near the S2 segment
C. Near the T10 to T11 disc
D. Near the L1 to L2 disc

D. Near the L1 to L2 disc The conus medullaris usually sits near L1 to L2. The dural sac continues to about S2, and the cord reaches about L3 at birth.

Spinal Biomechanics

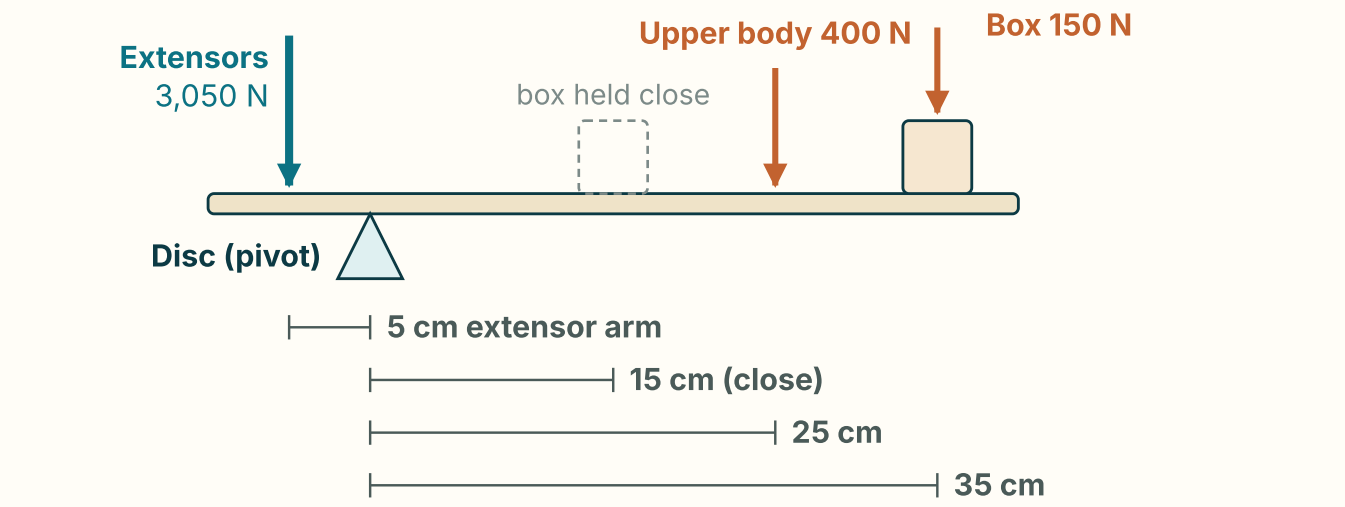
Read it in full: **Chapter 2 in the textbook**. See it in motion: **Spinal Biomechanics Walkthrough** and **Spinal Biomechanics Lab**.

What to know

Motion uses three planes with perpendicular axes, giving six degrees of freedom. Lower cervical coupling is same side (bodies toward the bend, spinous processes toward the convexity); thoracic and lumbar coupling is variable, so Fryette's Laws I and II are not dependable, while Law III fits. About half of cervical rotation is at C1 to C2; the ribs stiffen the thorax; lumbar segments flex and extend most at the bottom and rotate only 1 to 2 degrees each.

Tissues are viscoelastic (creep, stress relaxation, hysteresis). Compression puts the annulus in hoop tension and breaks the endplate first. Loaded flexion strains the posterior annulus; extension and rotation load the facets (right rotation compresses the left lumbar facet); shear stresses the pars. In vivo disc pressure is lowest lying down, highest lifting with a rounded back, and relaxed sitting is similar to standing.

Panjabi's passive, active and neural control subsystems share stability; the neutral zone widens with injury and narrows with muscle activity. Clinical instability threatens neural tissue; functional instability is poor control in normal range. Extensors act at about 5 cm, so keeping loads close cuts compression most, and no single posture prevents pain.



Moment	400 × 0.25 + 150 × 0.35 = 152.5 N·m
Extensor force	152.5 ÷ 0.05 = 3,050 N
Disc compression	3,050 + 500 above the disc = about 3,550 N
Box at 15 cm	122.5 N·m, 2,450 N, about 2,950 N of compression

Distance matters more than weight. The extensors act only 5 cm behind the disc, so every load held in front is multiplied. Moving the same 150 N box from 35 cm to 15 cm cuts the estimated compression by about 600 N.

LOCK THESE IN

- Sagittal plane: flexion and extension around a frontal axis. Frontal plane: lateral flexion around an AP axis. Transverse plane: rotation around a vertical axis.
- Six degrees of freedom: three rotations, three translations.
- Lower cervical coupling is same side and reliable. Lumbar coupling is small and variable; only Fryette's Law III fits the evidence.
- About 40 degrees of rotation each way at C1 to C2, about half of all neck rotation. Lumbar rotation is 1 to 2 degrees per segment.
- Creep, stress relaxation and hysteresis are the three viscoelastic behaviors.
- Flexion opens the back (posterior annulus); extension closes it (facets, pars); rotation jams the opposite facet; shear leans on the pars.
- Wilke: lying 0.1, standing 0.5, relaxed sitting about 0.46, rounded back 20 kg lift 2.3 MPa.
- Panjabi: passive, active, neural control. Neutral zone widens with injury, narrows with muscle.

Representative segmental motion (degrees)

Segment	Flexion plus extension	Lateral flexion, one side	Rotation, one side
Occiput to C1	About 25	About 5	About 5 or less
C1 to C2	About 20	About 5	About 40
C2 to C7, each	About 10 to 20, most at C5 to C6	About 5 to 10	About 5 to 10
Upper thoracic, each	About 4	About 6	About 8 to 9
Lower thoracic, each	About 6 to 12, rising toward T12	About 8 to 9	Falling to about 2 at T12 to L1
L1 to L5, each	About 12 to 16, rising caudally	About 6	About 2
L5 to S1	About 17 to 20	About 3	About 1

Worked cases

CASE 2.1 · ESTIMATING COMPRESSION WITH MOMENT ARMS

A worker leans forward so that 400 N of upper body weight acts 25 cm in front of the L5 to S1 disc. She holds a 150 N box 35 cm in front of the disc. The extensors act at 5 cm, and about 500 N of body weight sits above the disc. Estimate the compression, then redo it with the box held at 15 cm.

STEP 1 · FIND THE FLEXION MOMENT

(400 N × 0.25 m) + (150 N × 0.35 m) = 100 + 52.5 = **152.5 N·m**.

STEP 2 · FIND THE EXTENSOR FORCE

152.5 ÷ 0.05 = **3,050 N**.

STEP 3 · ADD THE WEIGHT ABOVE THE DISC

3,050 + 500 = about **3,550 N** of compression, just over the 3,400 N action limit the book quotes.

STEP 4 · BRING THE BOX CLOSE

Box moment 150 × 0.15 = 22.5 N·m. Total 100 + 22.5 = 122.5 N·m; extensor force 2,450 N; compression about **2,950 N**.

WHAT IT SHOWS

Moving the same box 20 cm closer cut the estimate by about 600 N. The model is two dimensional and ignores abdominal pressure and co-contraction, but it shows why distance matters more than weight.

CASE 2.2 · READING COUPLED MOTION IN THE NECK

A patient side bends the neck to the right. Viewed from behind, which way do the C3 to C6 bodies rotate and which way do the spinous processes move? Would the same rule apply at L3?

STEP 1 · RECALL THE CERVICAL RULE

Below C2, lateral flexion couples with rotation to the same side.

STEP 2 · MOVE THE BODIES

The bodies rotate to the **right**, toward the bend.

STEP 3 · MOVE THE SPINOUS PROCESSES

The spinous processes sit behind the axis, so they swing the other way, to the **left**, toward the convexity.

STEP 4 · TEST THE LOW BACK

No. Lumbar coupling is small and varies with person, level and starting posture, so the book says not to apply a fixed rule there.

TRAPS PEOPLE FALL INTO

- **Swapping planes and axes.** Sagittal plane motion turns around a frontal axis, and frontal plane motion turns around a sagittal (AP) axis.
- **Applying cervical coupling to the low back.** Same side coupling is reliable only below C2 in the neck. Lumbar coupling is variable.
- **Teaching Fryette's Laws I and II as fact.** Systematic reviews did not confirm them. Only Law III fits the evidence.
- **Saying sitting is far harder on the disc than standing.** That came from older needle data. In vivo data showed relaxed sitting similar to standing.
- **Thinking twisting happens in the lumbar spine.** Lumbar rotation is only 1 to 2 degrees per segment. Most trunk twist is hips and thoracic spine.

Chapter 2 self-test · six items

1. Rotation of the head on the neck happens in which plane, around which axis?

A. Frontal plane, around an AP axis
B. Sagittal plane, around a frontal axis
C. Transverse plane, around a frontal axis
D. Transverse plane, around a vertical axis

D. Transverse plane, around a vertical axis Axial rotation is transverse plane motion. The skewer through the moving joint would run straight up and down.

2. Which of Fryette's laws fits the research evidence?

A. Law I: opposite side coupling in neutral
B. All three laws, at every single level of the spine
C. Law III: motion in one plane limits the others
D. Law II: same side coupling in flexion

C. Law III: motion in one plane limits the others Law III matches experiments and everyday experience. Laws I and II have not held up as universal rules for the thoracic and lumbar spine.

3. During right axial rotation of a lumbar segment, which facet joint is compressed?

A. Both facet joints equally
B. The left facet joint
C. The right facet joint
D. Neither facet joint

B. The left facet joint The inferior facet on the side opposite the rotation presses into the superior facet below, and the same side facet gaps.

4. What did the late 1990s in vivo data show about relaxed sitting?

A. Disc pressure was similar to or lower than standing
B. Disc pressure was the same as lying supine
C. Disc pressure was about 40% higher than standing
D. Disc pressure was higher than in any of the lifting tasks

A. Disc pressure was similar to or lower than standing Relaxed sitting was about 0.46 MPa against about 0.5 MPa for standing. Older needle data had ranked unsupported sitting at about 140% of standing.

5. Which subsystem in Panjabi's model sets muscle activation in anticipation of a load?

A. The ligamentous subsystem
B. The neural control subsystem
C. The passive tissue subsystem
D. The active muscle subsystem

B. The neural control subsystem The neural control subsystem reads sensory input from the passive and active subsystems and sets activation patterns before and during loading.

6. Which change cuts spinal compression most during a lift, according to the lever model?

A. Lifting with a squat instead of a stoop
B. Lifting faster to finish sooner
C. Wearing a belt with no other change
D. Holding the load closer to the body

D. Holding the load closer to the body Back extensors act at only about 5 cm, so the load's distance from the spine drives extensor force. The book notes spinal load depends more on load distance than on squat versus stoop.

Joints, Cavitation and Tissue Response

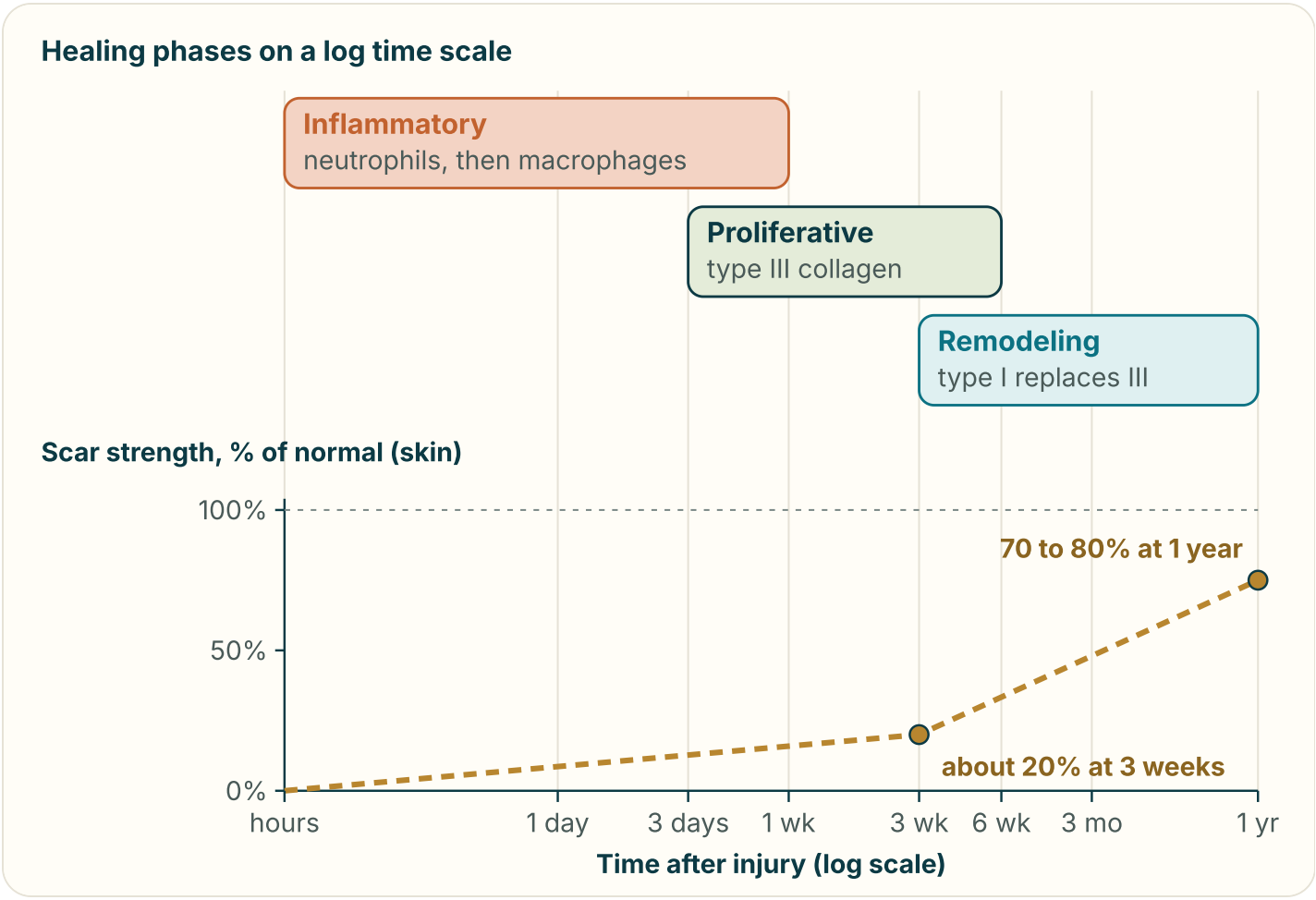
Read it in full: **Chapter 3 in the textbook**. See it in motion: **Joints and Cavitation Walkthrough** and **Joints and Cavitation Lab**.

What to know

A synovial joint is a sealed bearing: avascular hyaline cartilage fed by cyclic loading, synovium that makes hyaluronan and lubricin, and a richly innervated capsule. Facet joints are synovial plane joints with meniscoids, supplied by medial branches from their level and the level above.

Joint play is passive accessory motion, tested in the loose packed position. The convex concave rule predicts glide direction. End feels can be soft, firm or hard and normal; springy, spasm, boggy and empty are abnormal, and empty warns of serious pathology. Palpation for pain is fairly reliable; palpation for motion alone is not.

Cavitation is a gas cavity forming as sealed surfaces separate, with a refractory period of about 20 minutes; the pop is not repositioning and outcomes do not depend on it. Healing runs inflammatory, proliferative (type III collagen) and remodeling (type I) phases; blood supply sets the pace. Immobilization losses are fast and recovery slow, so graded loading drives rehabilitation.



Phases overlap, and strength lags behind. Inflammation settles within about a week, type III collagen fills the gap over weeks, and type I remodeling runs for a year or more. A skin scar is only about 20% as strong at 3 weeks and 70 to 80% at a year, long after pain fades.

LOCK THESE IN

- Cartilage: avascular, aneural, type II collagen and aggrecan, about 65 to 80% water, fed by cyclic loading.
- Type A synoviocytes clear debris; type B make hyaluronan and lubricin.
- Convex on concave: roll and glide opposite. Concave on convex: same direction.
- Close packed: most congruent, least play. Loose packed: most play, where joint play is tested.
- Empty end feel is never normal; a hard end feel is normal at elbow extension.
- Cavitation: gas forms as surfaces separate; refractory period about 20 minutes; not a bone moving into place.
- Healing: inflammatory (neutrophils then macrophages), proliferative (type III), remodeling (type I).
- Immobilization: fast loss, slow recovery. Wolff's law for bone, Davis's law for soft tissue.

End feels at a glance

End feel	What you feel	Normal example	When abnormal
Soft	Gradual squeezing stop	Knee or elbow flexion	Early stop from soft swelling
Firm	Leathery, slightly springy	Shoulder external rotation	Early firm stop: capsular tightness
Hard	Abrupt, unyielding	Elbow extension	Early hard stop: osteophyte, bony block
Springy block	Rebound before the expected end	None	Internal derangement (torn meniscus)
Spasm	Sudden muscular stop with pain	None	Guarding: acute injury, fracture, instability
Boggy	Soft, mushy stop	None	Effusion or marked swelling
Empty	Pain stops motion before resistance	None	Serious pathology: abscess, fracture, tumor

Worked cases

CASE 3.1 · CHOOSING A MOBILIZATION DIRECTION

A patient cannot fully abduct the shoulder, and joint play testing shows a stiff glide. Using the convex concave rule, which glide should the clinician restore, and where should it be tested?

STEP 1 · IDENTIFY THE MOVING SURFACE

In abduction the convex humeral head moves on the fixed, concave glenoid.

STEP 2 · APPLY THE RULE

Convex on concave means roll and glide go in opposite directions. The head rolls up, so it must glide **down** (inferiorly).

STEP 3 · PICK THE TECHNIQUE

An inferior glide of the humeral head is the logical accessory motion to restore.

STEP 4 · PICK THE POSITION

Test and start in the loose packed position, about 55 degrees of abduction with slight horizontal adduction, where play is greatest.

KEEP THE CAVEAT

The rule is a starting point. Real joints are not perfect spheres, and the flat spinal facets do not follow it neatly.

CASE 3.2 · READING TWO END FEELS

During passive knee flexion an examiner feels a gradual squeezing stop at full range. At another visit a patient with hip pain stops passive motion because of severe pain before the examiner feels any tissue resistance. Interpret each.

STEP 1 · ASK WHAT SHOULD STOP THE KNEE

At full knee flexion the calf meets the thigh, so a soft (tissue approximation) end feel is expected.

STEP 2 · JUDGE IT

It came at the expected point, so it is a **normal soft** end feel.

STEP 3 · LOOK AT THE HIP

Motion stopped by pain with no resistance felt is an **empty** end feel, which is never normal.

STEP 4 · DECIDE THE ACTION

Empty end feel raises concern for serious pathology such as acute bursitis, abscess, fracture or tumor, so it calls for careful evaluation before any manual treatment.

TRAPS PEOPLE FALL INTO

- **Calling a hard end feel abnormal.** It is normal at elbow extension. Judge whether it fits the joint and comes at the right point.
- **Testing joint play in the close packed position.** Close packing tightens the capsule and leaves almost no play. Use the resting position.
- **Explaining the pop as a bone going back in.** The refractory period shows a fluid and gas event. Imaging shows a gas cavity, not a change in bone position.
- **Treating the audible release as the goal.** Outcomes are similar with or without it, and it often comes from a neighboring segment.
- **Mixing up collagen types.** Type III is early repair. Type I replaces it during remodeling. Cartilage is type II.

Chapter 3 self-test · six items

1. Which statement about articular cartilage is correct?

A. It is built mainly of type I collagen fibers
B. It has a dense supply of free nerve endings
C. It is avascular and fed by cyclic loading
D. It is richly supplied by subchondral vessels

C. It is avascular and fed by cyclic loading Hyaline cartilage has no vessels, lymphatics or nerves. Its chondrocytes are fed by diffusion driven by compression and release.

2. Which end feel is never normal and raises concern for serious pathology?

A. Hard
B. Empty
C. Firm
D. Soft

B. Empty In an empty end feel the patient stops motion because of pain before the examiner feels any resistance. Soft, firm and hard can all be normal at the right joint.

3. Two examiners palpate the same patient's lumbar spine. On which judgment are they most likely to agree?

A. Whether pressing reproduces pain
B. Whether a vertebra is rotated
C. Which segment moves too little
D. Which spinous process is L4

A. Whether pressing reproduces pain Pain provocation has fair to good inter-examiner agreement. Motion and position judgments alone are poor to fair, and examiners often disagree about the level.

4. How long is the refractory period after a joint cavitates?

A. About 20 seconds
B. About 24 hours
C. About 2 minutes
D. About 20 minutes

D. About 20 minutes The gas cavity persists and slowly redissolves over roughly 20 to 30 minutes; until then the same maneuver cannot crack the joint again.

5. Which collagen type dominates new scar in the proliferative phase?

A. Type III
B. Type I
C. Type IV
D. Type II

A. Type III Fibroblasts lay down thin, quickly made type III collagen first. It is replaced by stronger type I during remodeling.

6. Which tissue truly regenerates rather than healing with scar?

A. Ligament
B. Bone
C. Tendon
D. Cartilage

B. Bone Bone heals through hematoma, soft callus, hard callus and remodeling with no scar, and can end as strong as the original.

Manipulation and Mobilization Mechanics

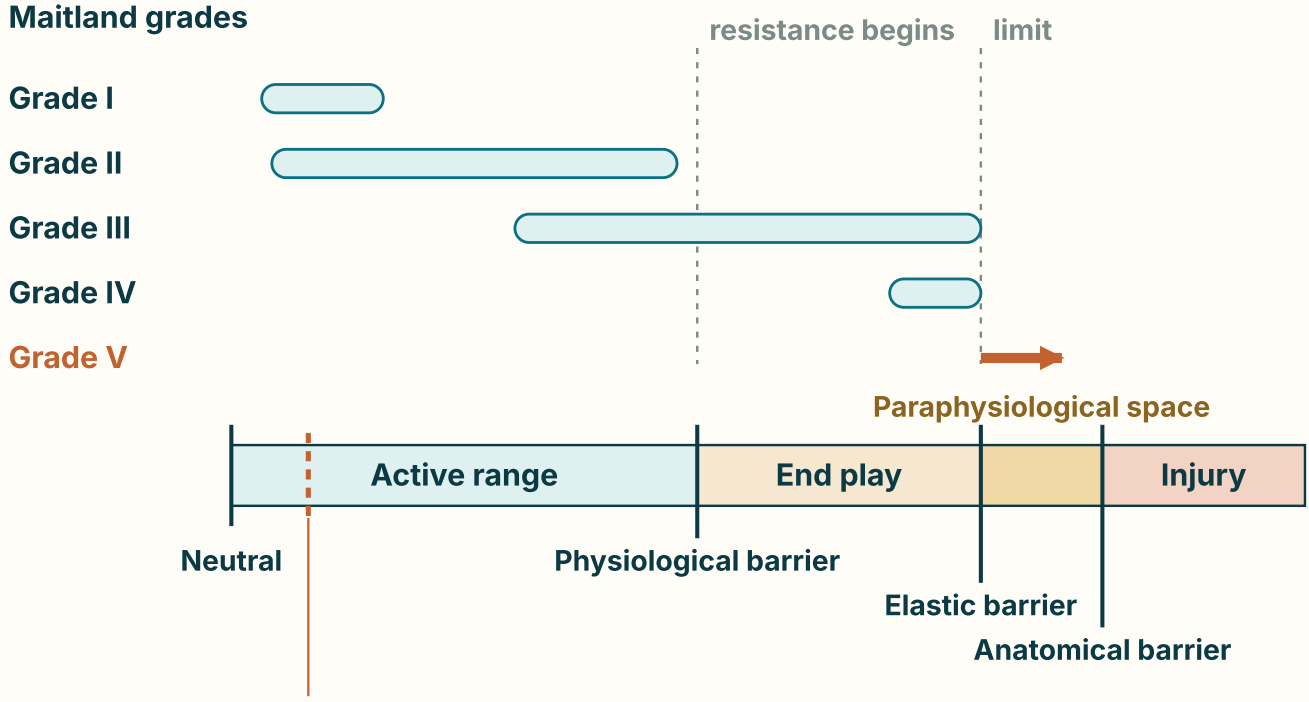
Read it in full: **Chapter 4 in the textbook**. See it in motion: **Manipulation and Mobilization Walkthrough** and **Manipulation and Mobilization Lab**.

What to know

Mobilization is slow, within range and stoppable by the patient; manipulation is a high velocity, low amplitude thrust at the end of passive range that the patient cannot stop. Maitland grades I to IV describe mobilization; grade V is manipulation. A thrust has preload, thrust (about 100 to 200 ms) and resolution; peaks run from about 100 N in the neck to several hundred newtons lower down. Rate of force application, not raw force, defines it.

The barrier model runs physiological barrier, elastic barrier, paraphysiological space and anatomical limit; a restrictive barrier appears early in dysfunction and is often neurological. Facet gapping and reduced stiffness are shown; meniscoid and adhesion release are unproven; lasting repositioning is not supported. Better supported effects are neurophysiological and brief, shaped by expectation.

Manipulation gives small to moderate short term benefit for low back and neck pain and is not supported for nonmusculoskeletal conditions. Mild reactions are common and brief; serious events are rare. Red flags lead to referral, contraindications to thrust lead to gentler care, and consent and reassessment complete the pathway.



Where each technique acts. Grades I and II stay short of resistance, III and IV work into it, and the grade V thrust passes the elastic barrier into the narrow paraphysiological space but never to the anatomical barrier.

LOCK THESE IN

- Manipulation: HVLA, end of passive range, patient cannot stop it. Mobilization: slow, patient can stop it.
- Maitland I and II stay short of resistance (pain); III and IV go into resistance (range); V is the thrust.
- Thrust phases: preload, thrust (about 100 to 200 ms), resolution.
- Rate = force ÷ time to peak (N/s). Impulse = force × time (N·s).
- Barriers outward: physiological, elastic, paraphysiological space, anatomical. Restrictive barrier comes early.
- Supported: small gapping, brief neurophysiological effects. Not supported: lasting repositioning.
- Mild reactions in about 30 to 60%, resolve in 24 to 72 hours.
- Five Ds, three Ns and ataxia: refer urgently, do not manipulate.

Maitland grades and thrust numbers

Item	Value or description	Purpose or note
Grade I	Small amplitude, start of range, before resistance	Pain relief in an irritable joint
Grade II	Large amplitude, within range, up to resistance	Pain relief, gentle movement
Grade III	Large amplitude, mid range into resistance	Increase range
Grade IV	Small amplitude, at the limit, into resistance	Increase range in a less irritable joint
Grade V	Very small, high velocity, past the passive limit	Manipulation (thrust)
Cervical HVLA	Peak about 100 to 150 N; preload often under 50 N	About 50 to 150 ms
Thoracic HVLA	Peak about 250 to 550 N; preload about 100 to 250 N	About 100 to 200 ms
Lumbar or SI side posture	Peak about 200 to 500 N; preload about 50 to 200 N	About 100 to 200 ms
Spring instrument	Up to a few hundred N at the tip	Under about 5 ms

Worked cases

CASE 4.1 · RATE OF FORCE AND IMPULSE

A thoracic thrust starts from a 150 N preload and rises to a 450 N peak in 150 ms. A second technique must deliver an impulse of 20 N·s. Find the rate of force application of the first thrust, and the average force needed if the second impulse is delivered in 100 ms or in 400 ms.

STEP 1 · FIND THE RISE

The force climbs from 150 N to 450 N, a rise of 300 N.

STEP 2 · DIVIDE BY THE TIME TO PEAK

300 N ÷ 0.150 s = **2,000 N/s**.

STEP 3 · REARRANGE IMPULSE

Impulse = force × time, so average force = impulse ÷ time.

STEP 4 · SOLVE BOTH TIMES

20 ÷ 0.1 = **200 N** in 100 ms; 20 ÷ 0.4 = **50 N** in 400 ms.

WHAT IT SHOWS

The same impulse delivered faster needs a higher force. The shorter thrust also sits in the 75 to 150 ms range where spindle discharge is greatest in animal studies.

CASE 4.2 · GRADING TWO TECHNIQUES

One clinician applies slow, large oscillations to a lumbar segment that move into resistance near end range. A colleague applies a quick, tiny thrust at the same point. Name each, and say which the patient could stop.

STEP 1 · DESCRIBE THE FIRST

Large amplitude, low velocity, from mid range into resistance: a **grade III mobilization**.

STEP 2 · DESCRIBE THE SECOND

Small amplitude, high velocity, just past the passive limit: a **grade V manipulation** (HVLA thrust).

STEP 3 · COMPARE CONTROL

The patient can stop the mobilization at any time. Once the thrust begins, the patient cannot stop it.

STEP 4 · PLACE IT ON THE BARRIER MODEL

Grade III acts up to the elastic barrier; the thrust enters the paraphysiological space but never reaches the anatomical barrier.

TRAPS PEOPLE FALL INTO

- **Defining manipulation by force.** It is defined by speed and small amplitude at the end of range. Peak forces are similar to lifting groceries.
- **Saying the thrust repositions a vertebra.** Imaging shows no lasting change in position. Displacements are tiny and shared across segments.
- **Believing a specific thrust moves one segment.** Neighboring vertebrae move almost as much as the target and often cavitate.
- **Treating a negative positional test as clearance.** Premanipulative positional tests have poor sensitivity and are not a reliable screen on their own.
- **Reading the stroke association as proof of cause.** Equal association with primary care visits suggests people seek care for an early dissection already underway.

Chapter 4 self-test · six items

1. Which Maitland grade is the manipulative thrust?

A. Grade V
B. Grade IV
C. Grade III
D. Grade I

A. Grade V Grade V is a very small, high velocity movement past the passive limit into the paraphysiological space.

2. Roughly how long does the thrust phase last in spinal manipulation?

A. About 10 to 20 ms
B. About 1 to 2 seconds
C. About 100 to 200 ms
D. About 5 to 10 seconds

C. About 100 to 200 ms Force time recordings show the thrust phase lasting on the order of 100 to 200 milliseconds in the spine.

3. Where does a restrictive barrier appear in a dysfunctional joint?

A. At the end of the paraphysiological space
B. Early, inside the normal range
C. Exactly at the physiological barrier
D. Beyond the anatomical barrier

B. Early, inside the normal range A restrictive or pathological barrier stops motion short of the normal end, from guarding, capsular shortening, adhesion, swelling or pain.

4. What does the evidence show about manipulation for infant colic and asthma?

A. Benefit equal to that seen for low back pain
B. Strong benefit in most randomized trials
C. Benefit only with instrument techniques
D. Well designed trials have not shown benefit

D. Well designed trials have not shown benefit Trials and reviews for asthma, high blood pressure, infant colic, otitis media and dysmenorrhea have not shown manipulation to be effective.

5. Why are premanipulative positional tests no longer recommended as a screen on their own?

A. They cause most dissections
B. They take too long to perform
C. They are always positive in older adults
D. They miss many patients at risk

D. They miss many patients at risk These tests have poor sensitivity. Guidance favors clinical reasoning about risk factors and signs of ischemia instead.

6. Which of these is an absolute contraindication to lumbar HVLA?

A. Osteopenia on a recent scan
B. Pregnancy in the second trimester
C. Suspected cauda equina syndrome
D. Radiculopathy with stable deficits

C. Suspected cauda equina syndrome Cauda equina syndrome needs emergency referral and no manual treatment. The others are relative contraindications that call for modification.

Nerve Roots, Dermatomes and Reflexes

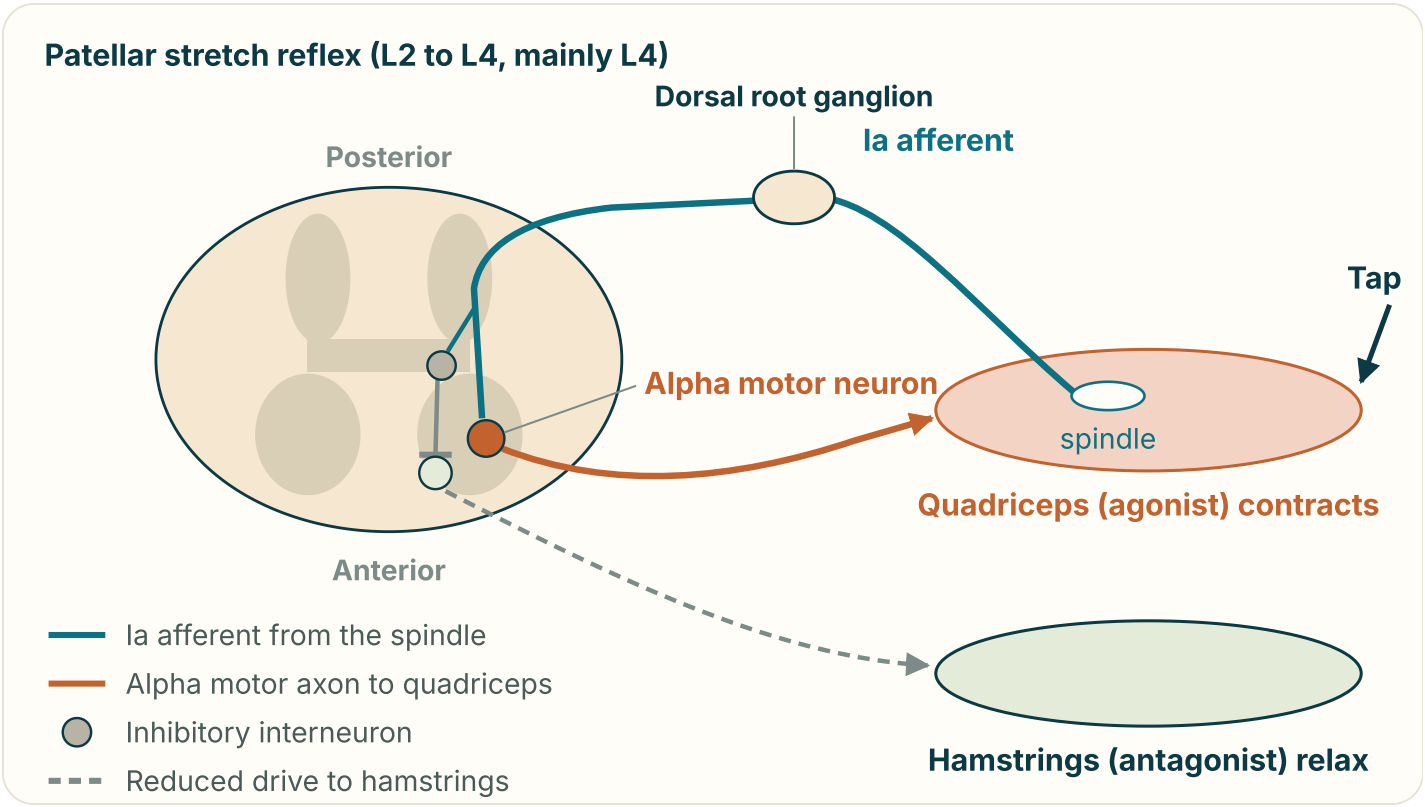
Read it in full: **Chapter 5 in the textbook**. See it in motion: **Nerve Roots Walkthrough** and **Nerve Roots Lab**.

What to know

Dorsal roots are sensory with cell bodies in the DRG; ventral roots are motor; they merge into a mixed spinal nerve that splits into dorsal and ventral rami. C1 to C7 exit above their vertebra, C8 between C7 and T1, and lower nerves below. The foramen is bounded by pedicles, disc and facet and narrows with extension and degeneration.

Anchors: C6 thumb, C7 middle finger, C8 little finger, T4 nipple, T10 umbilicus, L4 medial malleolus, L5 big toe and dorsum, S1 lateral foot. Reflexes: biceps C5, brachioradialis C6, triceps C7, patellar L4, Achilles S1. Upper motor neuron signs (spasticity, hyperreflexia, Babinski, Hoffmann, sustained clonus) point to the brain or cord.

Radicular pain shoots down the limb; radiculopathy is objective loss of function; somatic referred pain is deep and vague without deficit. Paracentral lumbar herniations hit the traversing root. The SLR is sensitive (rule out); crossed SLR and Spurling are specific (rule in). Entrapments mimic roots and are separated by sensory borders, the muscles involved, reflexes and spine signs.



One synapse, plus a brake on the antagonist. The Ia afferent synapses directly on the alpha motor neuron of the same muscle, which makes the reflex monosynaptic; a branch drives an inhibitory interneuron so the antagonist relaxes. Levels: biceps C5, brachioradialis C6, triceps C7, patellar L4, Achilles S1.

LOCK THESE IN

- 31 pairs: 8 C, 12 T, 5 L, 5 S, 1 Co. C8 exits between C7 and T1.
- Dorsal root sensory (DRG); ventral root motor. Dorsal ramus: back muscles and facets. Ventral ramus: plexuses and limbs.
- Anchors: C6 thumb, C7 middle finger, C8 little finger, T4 nipple, T10 umbilicus, L4 medial malleolus, L5 big toe, S1 lateral foot.
- Reflexes: biceps C5, brachioradialis C6, triceps C7, patellar L4, Achilles S1.
- Radiculopathy is defined by objective signs, not by pain.
- Paracentral herniation hits the traversing root; far lateral hits the exiting root.
- SLR sensitive, rules out. Crossed SLR and Spurling specific, rule in.
- Foot drop with normal inversion and hip abduction: fibular nerve, not L5.

Root syndromes

Root (usual disc)	Pain and sensory change	Weakness	Reflex
C5 (C4 to C5)	Shoulder and lateral upper arm	Shoulder abduction, elbow flexion	Biceps reduced
C6 (C5 to C6)	Lateral forearm, thumb, index finger	Elbow flexion, wrist extension	Brachioradialis and biceps
C7 (C6 to C7)	Back of arm and forearm, middle finger	Elbow extension, wrist flexion, finger extension	Triceps reduced
C8 (C7 to T1)	Medial forearm, ring and little fingers	Finger flexion, hand intrinsics	No standard reflex
L4 (L3 to L4; far lateral L4 to L5)	Anterior thigh, medial leg to medial malleolus	Knee extension, ankle dorsiflexion	Patellar reduced
L5 (L4 to L5)	Lateral leg, dorsum of foot, big toe	Great toe extension, dorsiflexion, inversion, hip abduction	Usually none
S1 (L5 to S1)	Back of calf, lateral foot, sole, little toe	Plantar flexion, eversion, hip extension	Achilles reduced

Worked cases

CASE 5.1 · PLACING A LUMBAR LESION

A 41 year old has shooting pain from the buttock down the back of the calf to the lateral foot. The right Achilles reflex is absent (left 2+), he cannot do ten single leg heel raises on the right, and the straight leg raise reproduces his leg pain at 45 degrees. Which root and which disc?

STEP 1 · READ THE SENSORY PATTERN

Back of the calf, lateral foot and sole belong to **S1**.

STEP 2 · READ THE MOTOR AND REFLEX FINDINGS

Weak plantar flexion and an absent Achilles reflex on one side both point to S1.

STEP 3 · CHECK THE PROVOCATION TEST

Leg pain below the knee between 30 and 70 degrees is a positive SLR for L5 or S1 irritation.

STEP 4 · NAME THE DISC

A posterolateral (subarticular) herniation at **L5 to S1** catches the traversing S1 root.

SCREEN FOR RED FLAGS

Ask about saddle numbness, bladder or bowel change and progressive weakness before planning conservative care.

CASE 5.2 · ROOT OR NERVE: FOOT DROP

A patient developed foot drop after weeks of crossing her legs while losing weight. Dorsiflexion and eversion are weak and the dorsum of the foot is numb. Inversion and hip abduction are strong, she has no back pain and the SLR is negative. Root or nerve?

STEP 1 · LIST THE SHARED FINDINGS

Weak dorsiflexion with dorsal foot numbness fits both L5 radiculopathy and common fibular nerve palsy.

STEP 2 · TEST THE SEPARATING MUSCLES

Inversion (tibialis posterior, tibial nerve) and hip abduction (gluteus medius, superior gluteal nerve) share the L5 root but not the fibular nerve.

STEP 3 · INTERPRET

Both are strong, so the lesion is distal to the root: **common fibular nerve** at the fibular neck.

STEP 4 · CONFIRM WITH CONTEXT

Leg crossing and weight loss that removes the nerve's fat padding are classic causes; no back pain and a negative SLR also argue against the root.

TRAPS PEOPLE FALL INTO

- **Assigning the big toe to S1.** The big toe and dorsum of the foot are L5. The little toe and lateral foot are S1.
- **Calling radicular pain radiculopathy.** Radiculopathy needs objective signs: numbness, weakness or a reduced reflex.
- **Counting back or hamstring pain as a positive SLR.** Only familiar leg pain below the knee counts.
- **Reading a positive SLR as proof of herniation.** The SLR is sensitive, not specific. A negative one is the useful result.

- **Expecting a Babinski sign from a lumbar herniation.** Below L1 to L2 the canal holds roots, so the picture is lower motor neuron.

Chapter 5 self-test · six items

1. Where are the cell bodies of the sensory neurons in a spinal nerve?

A. In the dorsal root ganglion
B. In the sympathetic chain ganglion
C. In the ventral horn of the cord
D. In the dorsal horn lamina II

A. In the dorsal root ganglion Sensory cell bodies sit in the dorsal root ganglion on the dorsal root, usually within the intervertebral foramen.

2. Which reflex chiefly tests the C7 root?

A. Achilles
B. Biceps
C. Triceps
D. Brachioradialis

C. Triceps Triceps is C7. Biceps is C5, brachioradialis C6 and Achilles S1.

3. Which finding is an upper motor neuron sign?

A. Marked early muscle atrophy
B. Sustained ankle clonus
C. Fasciculations in the calf
D. An absent Achilles reflex

B. Sustained ankle clonus Sustained clonus, hyperreflexia, spasticity and an extensor plantar response point to the upper motor neuron. The others are lower motor neuron findings.

4. A negative straight leg raise is useful mainly because the test is:

A. Painless, so it can be repeated daily
B. Specific, so it helps rule in herniation
C. Objective, so it defines radiculopathy
D. Sensitive, so it helps rule out herniation

D. Sensitive, so it helps rule out herniation SnNout: a negative result on a sensitive test makes a lumbar disc herniation unlikely.

5. Why is the thenar skin spared in carpal tunnel syndrome?

A. It is supplied by the radial nerve
B. It lies inside Guyon canal
C. It is supplied by the C8 root
D. Its branch leaves above the wrist

D. Its branch leaves above the wrist The palmar cutaneous branch of the median nerve leaves above the wrist and passes over the transverse carpal ligament, outside the tunnel.

6. Burning numbness on the outer thigh with normal strength and reflexes points to which problem?

A. L3 radiculopathy
B. Deep gluteal syndrome
C. Meralgia paresthetica
D. Femoral neuropathy

C. Meralgia paresthetica Compression of the lateral femoral cutaneous nerve near the ASIS is purely sensory, which separates it from an L2 or L3 root lesion.

Pain Neuroscience

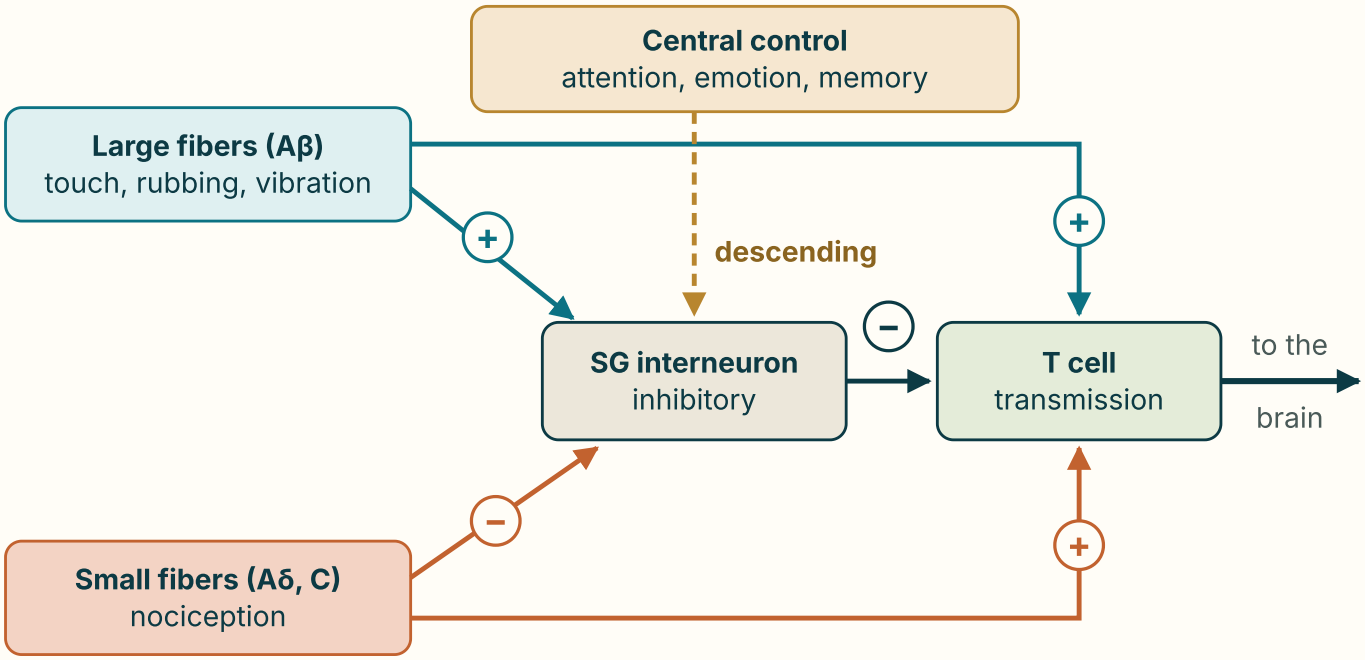
Read it in full: **Chapter 6 in the textbook**. See it in motion: **Pain Neuroscience Walkthrough** and **Pain Neuroscience Lab**.

What to know

Pain is a personal sensory and emotional experience; nociception is the neural encoding of noxious stimuli, and each can occur without the other. Aδ fibers carry first pain and C fibers second pain; the spinothalamic tract crosses early and feeds a distributed brain network. Mechanisms are nociceptive, neuropathic or nociplastic, often mixed.

Peripheral sensitization from inflammatory mediators causes primary hyperalgesia. Central sensitization (NMDA receptors, wind-up, disinhibition, glia, descending facilitation) causes allodynia, secondary hyperalgesia and spreading pain. In gate control, large fibers and descending control close the gate and small fibers open it. The PAG, RVM and locus coeruleus inhibit or facilitate pain with opioids, serotonin and norepinephrine.

Chronic pain lasts beyond three months and fits the biopsychosocial model. Catastrophizing and fear drive the fear avoidance cycle; graded exposure breaks it. Pain education works best with exercise; avoid nocebo language and remember that imaging findings are common in people without pain.



Large fibers close the gate, small fibers open it, and descending control from the brain sets it. Pain depends on the balance of all three inputs, not on the nociceptive signal alone.

Large closes, small opens. Melzack and Wall placed a gate in the dorsal horn: touch fibers excite an inhibitory interneuron that damps the transmission cell, nociceptive fibers inhibit that interneuron, and the brain reaches down to set the gate.

LOCK THESE IN

- Nociception is input; pain is output. Each can occur without the other.
- Aδ: fast, thinly myelinated, first pain. C: slow, unmyelinated, second pain. Aβ: touch.
- Spinothalamic tract crosses within a segment or two: hemisection loses pain and temperature on the opposite side.
- Allodynia: harmless stimulus hurts. Hyperalgesia: painful stimulus hurts more.
- Primary hyperalgesia is peripheral; secondary hyperalgesia is central.
- Gate control: large closes, small opens, brain sets it.
- Descending chain: PAG to RVM (serotonin) plus locus coeruleus (norepinephrine) to the dorsal horn.
- Chronic means more than three months. Catastrophizing: rumination, magnification, helplessness.

Fibers and pain mechanisms

Item	Key facts	Example or note
Aβ fiber	Thick myelin, about 35 to 75 m/s; touch, vibration	Closes the gate; drives allodynia when disinhibited
Aδ fiber	Thin myelin, about 5 to 30 m/s; first pain, cold	Laminae I and V
C fiber	Unmyelinated, about 0.5 to 2 m/s; second pain, warmth, itch	Laminae I and II (substantia gelatinosa)
Nociceptive pain	Damage to non neural tissue; localized, proportionate	Ankle sprain, facet strain
Neuropathic pain	Lesion or disease of the somatosensory system	Radiculopathy, postherpetic neuralgia
Nociplastic pain	Altered nociception without clear damage or lesion	Fibromyalgia, some chronic low back pain
Peripheral sensitization	Inflammatory mediators at nociceptor terminals	Primary hyperalgesia
Central sensitization	NMDA, wind-up, disinhibition, glia, facilitation	Allodynia, secondary hyperalgesia

Worked cases

CASE 6.1 · NAMING THE PAIN MECHANISM

Three patients: (1) an acute ankle sprain that hurts with weight bearing and eases with rest; (2) burning, electric pain in the S1 distribution with a reduced Achilles reflex; (3) widespread pain, poor sleep, fatigue and sensitivity to light and sound with no clear lesion. Classify each.

STEP 1 · PATIENT 1

Damage to non neural tissue, localized and mechanical: **nociceptive**.

STEP 2 · PATIENT 2

A lesion of the somatosensory system (the S1 root) with burning, shooting pain in its territory: **neuropathic**.

STEP 3 · PATIENT 3

Altered nociception without clear damage or a nerve lesion, with widespread hypersensitivity: **nociplastic**.

REMEMBER THE OVERLAP

One person with chronic low back pain may have all three contributions, in proportions that change over time.

CASE 6.2 · READING IMAGING IN A PERSON WITH NO PAIN

Using the pooled estimates for people without back pain, how many of 100 pain free 50 year olds would show disc degeneration, and how many disc bulges? What does that mean for a 50 year old patient whose report shows both?

STEP 1 · FIND THE RATES

At age 50 the estimates are about 80% for disc degeneration and about 60% for disc bulge.

STEP 2 · APPLY THEM

Of 100 pain free 50 year olds, about **80** would show degeneration and about **60** a bulge.

STEP 3 · INTERPRET

These findings are the norm at that age, so they cannot by themselves explain one person's pain.

STEP 4 · CHOOSE WORDS

Explain them as normal age changes, like wrinkles on the inside, and match any finding to the clinical picture. Guidelines advise against routine imaging without red flags.

TRAPS PEOPLE FALL INTO

- **Equating nociception with pain.** Nociception is input; pain is a constructed output that can occur without it.
- **Mixing up the two hyperalgesias.** Primary lives in the injured tissue; secondary lives around it and reflects cord changes.
- **Reversing the gate.** Large fibers close the gate. Small fibers open it.
- **Putting the lesion on the wrong side.** Spinothalamic fibers cross early, so a right hemisection loses pain and temperature on the left.
- **Reading biopsychosocial as all in the head.** The model keeps biology and adds psychological and social factors.

Chapter 6 self-test · six items

1. Which statement best describes the relation between nociception and pain?

A. Nociception is input; pain is an output
B. Pain always requires nociception first
C. Nociception always produces pain
D. They are one and the same process

A. Nociception is input; pain is an output Nociception is the neural encoding of noxious stimuli. Pain is an experience the brain may or may not construct from it.

2. Which type of pain arises from a lesion or disease of the somatosensory nervous system?

A. Nociceptive
B. Somatic referred
C. Neuropathic
D. Nociplastic

C. Neuropathic Neuropathic pain, such as radiculopathy or postherpetic neuralgia, is defined by a lesion or disease of the somatosensory system.

3. Increased sensitivity in uninjured tissue around an injury reflects which change?

A. Peripheral sensitization in the wound
B. Central sensitization in the cord
C. Damage to the somatosensory cortex
D. Loss of C fibers in the skin

B. Central sensitization in the cord Secondary hyperalgesia lives outside the injured tissue, so the change must be where signals converge, in the spinal cord.

4. Which midbrain region drives descending pain inhibition and is rich in opioid receptors?

A. Locus coeruleus
B. Substantia gelatinosa
C. Ventral posterolateral thalamus
D. Periaqueductal gray

D. Periaqueductal gray Stimulating the PAG produced analgesia deep enough for surgery in rats, which led to the discovery of the endogenous opioid system.

5. How long must pain persist or recur to be called chronic?

A. More than one full year
B. More than two weeks
C. More than three months
D. More than six weeks

C. More than three months Chronic pain is pain that persists or recurs beyond three months, when most tissues have passed their early healing phases.

6. Which phrase is the least threatening way to describe a disc bulge to a patient?

A. You have a slipped disc that is out of place
B. Your spine is degenerating faster than normal
C. Your back has gone out of its alignment
D. A disc is irritating a nerve; most settle well

D. A disc is irritating a nerve; most settle well Accurate, low threat language lowers the nocebo effect. Discs do not slip, and the body often reabsorbs a bulge.

Exam Logic and Red Flags

Read it in full: **Chapter 7 in the textbook**. See it in motion: **Exam Logic and Red Flags Walkthrough** and **Exam Logic and Red Flags Lab**.

What to know

The history sets the pretest probability and triage sorts patients into serious pathology (about 1%), radicular syndromes (5 to 10%) and nonspecific pain (about 90%). Mechanical pain changes with movement; nonmechanical pain prompts a search. Neurogenic claudication eases with flexion and sitting; vascular claudication eases with any rest.

Sensitivity is a / (a + c) and specificity d / (b + d): SnNout and SpPin. LR+ = sens ÷ (1 − spec); LR− = (1 − sens) ÷ spec; always combine with pretest probability. Upper motor neuron signs suggest myelopathy and mean referral, not manipulation.

Red flags are common and mostly weak alone; a history of cancer is the strongest. Cauda equina syndrome needs same day emergency MRI. Dissection needs emergency referral. Yellow flags predict chronicity and are stratified with the STarT Back Tool. Match urgency to how fast harm could occur and write referrals with SBAR.

Reference standard (MRI)

	Herniation present	Herniation absent
Test +	a **45** True positive	b **30** False positive
Test –	c **5** False negative	d **120** True negative
	a + c = 50	**b + d = 150**

Sensitivity
a / (a + c) = 45 / 50 = 0.90

Specificity
d / (b + d) = 120 / 150 = 0.80

LR+
0.90 / (1 − 0.80) = 4.5

LR−
(1 − 0.90) / 0.80 = 0.125

SnNout: high sensitivity, few false negatives, so a negative result rules out.
SpPin: high specificity, few false positives, so a positive result rules in.

Read sensitivity down one column, specificity down the other. With 45 of 50 true cases caught and 120 of 150 non cases cleared, this test has a sensitivity of 0.90 and a specificity of 0.80, so its LR− of 0.125 makes it better for ruling out than its LR+ of 4.5 is for ruling in.

LOCK THESE IN

- Triage: serious about 1%, radicular 5 to 10%, nonspecific about 90%.
- Sensitivity = a/(a+c); specificity = d/(b+d). SnNout, SpPin.
- LR+ = sens/(1 − spec); LR− = (1 − sens)/spec. Over 10 or under 0.1 is decisive.
- SLR: sensitive (about 0.9), not specific (about 0.25). Crossed SLR and Spurling: specific.
- History of cancer is the strongest single red flag (LR+ about 7 to 15).
- CES: saddle anesthesia, urinary retention or change, bowel and sexual change, bilateral leg symptoms: same day.
- Yellow flags threaten recovery, not the body. Low expectation of recovery is a strong predictor.
- Urgency tiers: emergency same day, urgent within days, routine within weeks. SBAR.

Red flag patterns and next steps

Condition	Most useful flags	Usual next step
Malignancy	History of cancer; age over 50 with weight loss, night pain, failure to improve	Urgent imaging and labs; emergency if new neurological signs
Infection	Injection drug use, immunosuppression, recent infection or procedure; fever; focal pain	Same day or urgent: ESR, CRP, cultures, MRI
Fracture	Age over 70, long term steroids, significant trauma, contusion	Radiographs; Canadian C-spine or NEXUS after neck trauma
Cauda equina syndrome	Saddle anesthesia, urinary change or retention, bowel or sexual change, bilateral legs	Emergency department the same day
Abdominal aortic aneurysm	Older male smoker, nonmechanical deep pain, pulsatile mass	Emergency if symptomatic
Cervical artery dissection	New unusual neck pain or headache; five Ds, three Ns, ataxia	Emergency services; no manipulation
Inflammatory spondyloarthritis	Onset before 45, stiffness over 30 min, better with exercise, alternating buttock pain	Routine to urgent rheumatology

Worked cases

CASE 7.1 · BUILDING A TWO BY TWO TABLE

A new test is checked against MRI in 200 patients. Of 50 with a herniation, 45 test positive. Of 150 without one, 120 test negative. Find sensitivity, specificity and both likelihood ratios. Is it better for ruling in or ruling out?

STEP 1 · FILL THE TABLE

a (true positive) = 45, c (false negative) = 5, b (false positive) = 150 − 120 = 30, d (true negative) = 120.

STEP 2 · SENSITIVITY

45 ÷ 50 = **0.90**.

STEP 3 · SPECIFICITY

120 ÷ 150 = **0.80**.

STEP 4 · LIKELIHOOD RATIOS

LR+ = 0.90 ÷ 0.20 = **4.5**. LR− = 0.10 ÷ 0.80 = **0.125**.

STEP 5 · INTERPRET

LR− of 0.125 is a moderate to strong rule out; LR+ of 4.5 is a small to moderate rule in. The test is better for ruling out.

CASE 7.2 · WHY PRETEST PROBABILITY MATTERS

A test has an LR+ of 5. Patient A has a 1% pretest probability of the condition; patient B has 40%. Both test positive. Find each posttest probability.

STEP 1 · CONVERT TO ODDS

Odds = p ÷ (1 − p). A: 0.01 ÷ 0.99 = 0.0101. B: 0.40 ÷ 0.60 = 0.667.

STEP 2 · MULTIPLY BY THE LR

A: 0.0101 × 5 = 0.0505. B: 0.667 × 5 = 3.33.

STEP 3 · CONVERT BACK

p = odds ÷ (1 + odds). A: 0.0505 ÷ 1.0505 = about **5%**. B: 3.33 ÷ 4.33 = about **77%**.

THE LESSON

The same positive result leaves patient A unlikely to have the condition and makes it likely for patient B. The history, which sets the pretest probability, decides what a test means.

TRAPS PEOPLE FALL INTO

- **Reversing SnNout and SpPin.** Sensitivity is about the sick, so its strength is a negative result. Specificity rules in.
- **Treating any red flag as an alarm.** Most single flags are weak. Weigh them in combination, in context and over time.
- **Reading night pain as sinister.** Pain that eases with a change of position is mechanical. Constant, progressive night pain is the concern.
- **Waiting for retention before acting on CES.** Outcomes are far better if decompression happens before retention. Act on early features.
- **Trusting a negative positional test for the vertebral artery.** These tests have poor validity. Screen for symptoms of ischemia instead.

Chapter 7 self-test · six items

1. About what share of acute low back pain in primary care is serious spinal pathology?

A. About 25%
B. About 1%
C. About 10%
D. About 50%

B. About 1% Serious pathology is about 1%, radicular syndromes about 5 to 10% and nonspecific pain about 90%.

2. What is the formula for the negative likelihood ratio?

A. sensitivity ÷ (1 − specificity)
B. specificity ÷ (1 − sensitivity)
C. (1 − specificity) ÷ sensitivity
D. (1 − sensitivity) ÷ specificity

D. (1 − sensitivity) ÷ specificity LR− is the false negative rate divided by the true negative rate. LR+ is sensitivity divided by one minus specificity.

3. Which finding is the most consistent in established cauda equina syndrome?

A. Urinary retention
B. Localized facet pain
C. Fever and chills
D. Unilateral foot drop

A. Urinary retention Painless urinary retention with overflow is the most consistent finding in established cases; earlier stages show altered urinary sensation.

4. Pain relieved within minutes by standing still after walking a fixed distance suggests which cause?

A. Neurogenic claudication
B. Cervical myelopathy
C. Vascular claudication
D. Somatic referred pain

C. Vascular claudication Arterial pain eases with any rest. Neurogenic claudication needs sitting or bending forward.

5. What does the STarT Back Tool stratify?

A. Need for emergency imaging
B. Risk of vertebral fracture after trauma
C. Probability of spinal malignancy
D. Risk of persistent disabling back pain

D. Risk of persistent disabling back pain The nine item tool combines physical and psychosocial items to sort patients into low, medium and high risk, guiding stratified care.

6. In an SBAR referral, which part states what you are asking for and how soon?

A. Background
B. Recommendation
C. Situation
D. Assessment of risk

B. Recommendation Recommendation holds the specific request and time frame, plus the safety netting advice given to the patient.

Posture, Gait and Movement

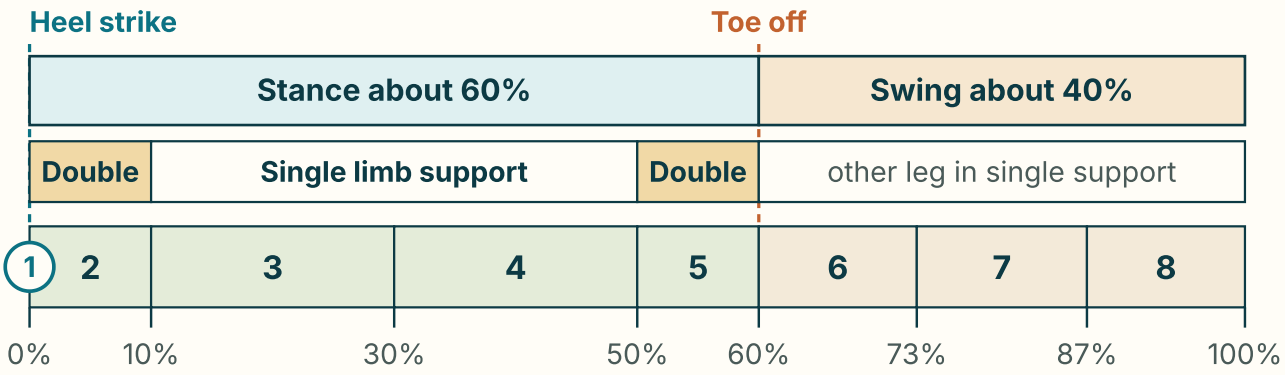
Read it in full: **Chapter 8 in the textbook**. See it in motion: **Posture and Gait Walkthrough** and **Posture and Gait Lab**.

What to know

The ideal plumb line passes through the ear, acromion, lumbar bodies, greater trochanter, just in front of the knee and just in front of the lateral malleolus, but static posture is a weak predictor of pain. Forward head posture and the crossed syndromes are plausible but weakly linked to pain. Scoliosis is a Cobb angle of 10 degrees or more; the forward bend test separates structural from functional curves.

The gait cycle is about 60% stance and 40% swing with two double support periods of about 10% each that vanish in running. The heel, ankle and forefoot rockers carry the body forward, with many eccentric muscle bursts. Gait speed below about 0.8 m/s signals risk; street crossing needs about 1.2 m/s.

Antalgic gait shortens stance on the painful side; Trendelenburg reflects weak abductors on the stance side; steppage reflects foot drop. Central gaits point to brain and cord, and Romberg identifies sensory ataxia. The TUG screens fall risk. Relaxed sitting is close to standing for disc pressure; bending and lifting raise it most; variety, activity and gradual load tolerance matter more than one posture.



1 Initial contact (0%)
2 Loading response (0 to 10%)
3 Midstance (10 to 30%)
4 Terminal stance (30 to 50%)
5 Preswing (50 to 60%)
6 Initial swing (60 to 73%)
7 Midswing (73 to 87%)
8 Terminal swing (87 to 100%)

Double support shrinks as speed rises and disappears in running, replaced by a flight phase.

Stance, swing and the two double supports. At normal speed stance takes about 60% of the cycle and swing about 40%, framed by two double support periods of about 10% each. Five phases belong to stance and three to swing.

LOCK THESE IN

- Plumb line: earlobe, acromion, lumbar bodies, greater trochanter, slightly in front of knee and lateral malleolus.
- Scoliosis: Cobb 10 degrees or more; forward bend hump means structural.
- Gait: stance about 60%, swing 40%, two double supports of about 10% each.
- Rockers: heel, ankle, forefoot. Early stance shock absorbers: dorsiflexors and quadriceps, eccentric.
- Speed = step length × cadence. Below 0.8 m/s is a risk; street crossing needs about 1.2 m/s.
- Trendelenburg: the side that stands is the side that is weak (gluteus medius, superior gluteal nerve).
- Positive Romberg (worse with eyes closed) means lost proprioception: sensory ataxia.
- TUG 12 seconds or more suggests fall risk. Relaxed sitting 0.46 versus standing 0.50 MPa.

The eight phases of gait

Phase	% of cycle	Key events
Initial contact	0	Hip about 30 degrees flexed, knee near extension, ankle neutral
Loading response	0 to 10	Ankle plantar flexes 5 to 10 degrees (eccentric dorsiflexors); knee flexes 15 to 20 (eccentric quadriceps)
Midstance	10 to 30	Single support; tibia advances; abductors hold the pelvis level
Terminal stance	30 to 50	Heel rises; hip about 10 degrees apparent extension; calf working hard
Preswing	50 to 60	Second double support; plantar flexion 15 to 20; toe off ends stance
Initial swing	60 to 73	Knee flexes to its peak of about 60 degrees
Midswing	73 to 87	Swing limb passes the stance limb; ankle to neutral for clearance
Terminal swing	87 to 100	Knee extends; hamstrings decelerate eccentrically

Worked cases

CASE 8.1 · GAIT SPEED FROM STEP LENGTH AND CADENCE

A healthy adult walks with a 0.7 m step length at 110 steps per minute. An older patient walks 10 m in 12.5 seconds. Find each speed in m/s and interpret the patient's value.

STEP 1 · APPLY THE FORMULA

Speed = step length × cadence = 0.7 m × 110 steps/min = 77 m/min.

STEP 2 · CONVERT TO M/S

77 ÷ 60 = **1.28 m/s**, inside the healthy range of about 1.2 to 1.4 m/s.

STEP 3 · TIME THE PATIENT

10 m ÷ 12.5 s = **0.80 m/s**.

STEP 4 · INTERPRET

About 0.8 m/s is the threshold for limited community walking and higher risk, and well below the about 1.2 m/s needed to cross a street before the signal changes.

CASE 8.2 · READING A TRENDELENBURG SIGN

A patient stands on the left leg, and the right side of the pelvis drops. Which muscles are weak, which nerve supplies them, and what would a compensated gait look like?

STEP 1 · FIND THE STANCE LEG

The left leg is on the ground, so the left hip abductors must hold the pelvis level.

STEP 2 · NAME THE WEAK MUSCLES

The **left gluteus medius and minimus** are failing. The side that stands is the side that is weak.

STEP 3 · NAME THE NERVE

The superior gluteal nerve (L4 to S1) supplies them; causes include nerve injury, L5 radiculopathy, hip osteoarthritis, dysplasia and gluteal tendinopathy.

STEP 4 · DESCRIBE COMPENSATION

In a compensated Trendelenburg gait the trunk leans over the left stance leg, moving the center of mass over the hip and reducing the abductor force needed.

TRAPS PEOPLE FALL INTO

- **Predicting pain from a slumped posture.** Static posture correlates weakly with pain. Healthy people vary widely.
- **Blaming the side that drops.** In the Trendelenburg sign the weak abductors are on the stance side.
- **Calling any standing curve scoliosis.** A functional curve straightens on sitting or bending. Structural scoliosis keeps a rotational hump.
- **Thinking the Romberg tests the cerebellum.** It tests proprioception. Cerebellar ataxia is unsteady even with eyes open.
- **Saying sitting is the worst position for the disc.** In vivo relaxed sitting (0.46 MPa) is close to standing (0.50 MPa).

Chapter 8 self-test · six items

1. Which bony landmark does the ideal side view plumb line pass through at the hip?

A. Through the ischial tuberosity
B. Through the pubic symphysis
C. Near the greater trochanter
D. Through the ASIS

C. Near the greater trochanter The line passes through or just behind the hip joint near the greater trochanter, pushing the hip into extension against the iliofemoral ligament.

2. What Cobb angle defines scoliosis?

A. 5 degrees or more
B. 40 degrees or more
C. 20 degrees or more
D. 10 degrees or more

D. 10 degrees or more Scoliosis is a lateral curve with rotation measuring 10 degrees or more on a radiograph.

3. Which rocker involves the calf's largest burst of power?

A. Forefoot rocker
B. Ankle rocker
C. Heel rocker
D. Midfoot rocker

A. Forefoot rocker In terminal stance the body rolls over the metatarsal heads and the calf produces its push off, with the windlass mechanism stiffening the foot.

4. What gait speed is about the minimum needed to cross a typical street before the signal changes?

A. About 0.4 m/s
B. About 1.2 m/s
C. About 0.8 m/s
D. About 2.0 m/s

B. About 1.2 m/s Crossing a typical street needs about 1.2 m/s. Below about 0.8 m/s signals limited community walking.

5. A positive Romberg sign mainly indicates loss of what?

A. Hip abductor power
B. Joint position sense
C. Cerebellar function
D. Dorsiflexor strength

B. Joint position sense Swaying only with eyes closed means vision was covering for lost joint position sense, as in sensory ataxia.

6. In the in vivo study, which position produced disc pressure closest to relaxed standing?

A. Lying supine
B. Standing bent forward
C. Relaxed sitting
D. Lifting with knees bent

C. Relaxed sitting Relaxed sitting was about 0.46 MPa and relaxed standing about 0.50 MPa, revising the older claim that sitting is far worse.

Chiropractic Models Through History

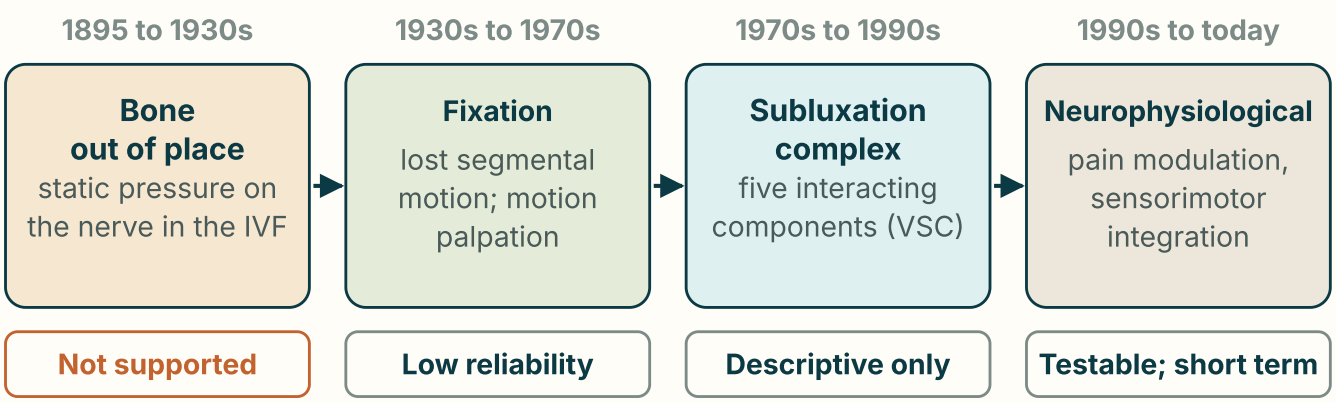
Read it in full: **Chapter 9 in the textbook**. See it in motion: **Chiropractic Models Walkthrough** and **Chiropractic Models Lab**.

What to know

D.D. Palmer, a magnetic healer in Davenport, adjusted Harvey Lillard in 1895 and taught from 1897. He combined magnetic healing, bonesetting, ideas shared with osteopathy (1874) and vitalism into a theory of tone, Innate Intelligence and displaced vertebrae. The cochlear nerve never passes through the spine, and the claim that displaced vertebrae cause most disease has not held up.

B.J. Palmer introduced spinography (1910), radio promotion (1922), the divisive neurocalometer (1924) and Hole in One upper cervical work. The 1907 Morikubo acquittal made a unique philosophy a legal shield; licensure ran from Kansas (1913) to Louisiana (1974). Straights, mixers, objective straights and reformers form a spectrum; the ICA (1926), NCA (1930) then ACA (1963) and the CCE (1974) grew from it.

The chiropractic subluxation moved from a bone out of place to fixation, the five part VSC and neurophysiological models; the medical subluxation is a partial dislocation. Detection is unreliable and there is no good evidence that subluxations cause disease, while manipulation has modest support for spinal pain. Medicare documentation uses PART: two elements, one of them A or R.



Evidence row: how each idea has fared when tested.

Trend: from a visible structural cause of disease toward measurable functional effects on pain and movement. All four still coexist in practice.

Throughout: subluxation detection is unreliable (kappa often below 0.4), and there is no good evidence that subluxations cause organ disease.

Four models of one word. The chiropractic subluxation moved from a displaced bone to lost motion, then to a five part complex, then to neurophysiological effects of the thrust. The medical subluxation, a partial dislocation, is a different thing.

LOCK THESE IN

- 1874 osteopathy, 1892 first osteopathic school, 1895 Lillard, 1897 first chiropractic school.
- D.D.: tone, Innate Intelligence, displaced vertebra; about 95% of disease claimed.
- B.J.: spinography 1910, radio 1922, neurocalometer 1924, Hole in One about 1930.
- Morikubo 1907: chiropractic argued distinct from osteopathy; acquitted.
- Licensure: Kansas 1913 first, Louisiana 1974 last. CCE recognized 1974.
- ICA 1926 (straight); NCA 1930 became ACA 1963 (broad scope); reform group 1984.
- VSC: kinesiopathology, neuropathology, myopathology, histopathology, biochemical.
- PART: two of four, one must be asymmetry or range of motion abnormality.

Timeline of the founding era

Year	Event	Why it mattered
1895	Lillard adjustment	Founding moment; Roentgen discovers x-rays the same year
1897	D.D. begins teaching in Davenport	First school; B.J. among early graduates
1906	D.D. jailed; B.J. takes the school; UCA founded	Organized legal defense begins
1907	Morikubo acquitted in Wisconsin	Distinct science argument; philosophy as legal shield
1910	Spinography; *The Chiropractor's Adjuster*	Radiography enters practice; theory in print
1913	Kansas license; D.D. dies	State licensure begins
1924	Neurocalometer	Bitter split; B.J. loses the UCA
1926	ICA founded	Home of the straight position
1930s	Hole in One upper cervical technique	Focus on atlas and axis
1961	B.J. dies	End of family dominance
1974	Louisiana licenses; CCE recognized	Licensure in all states; accreditation

Worked cases

CASE 9.1 · CHECKING PART DOCUMENTATION

A Medicare patient has (1) tenderness and pain at L3 with paraspinal hypertonicity and normal alignment and motion; (2) tenderness at L3 and reduced, painful L3 to L4 motion. Which visit documents a subluxation under PART?

STEP 1 · RECALL THE RULE

At least two of the four PART elements must be present, and one of them must be A (asymmetry or misalignment) or R (range of motion abnormality).

STEP 2 · SCORE VISIT 1

P (pain and tenderness) and T (tissue tone) are present, but neither A nor R. Two elements, but the required one is missing: **not documented**.

STEP 3 · SCORE VISIT 2

P and R are present. Two elements, and one is R: **documented**.

NOTE THE WIDER POINT

Coverage rests on this vocabulary, so even chiropractors who reject the traditional theory must document subluxation for Medicare patients.

CASE 9.2 · TESTING THE FOUNDING STORY WITH ANATOMY

Palmer explained Lillard's improved hearing as a thoracic vertebra no longer pressing on a nerve. Test the explanation in steps.

STEP 1 · IDENTIFY THE NERVE OF HEARING

Hearing depends on the cochlear part of cranial nerve VIII.

STEP 2 · TRACE ITS PATH

It runs from the inner ear through the internal acoustic meatus straight to the brainstem.

STEP 3 · COMPARE WITH THE CLAIM

It never exits through a vertebral foramen, so a displaced thoracic vertebra could not compress it.

STEP 4 · CONCLUDE

Whatever happened to Lillard's hearing, the stated mechanism cannot be the cause. The event still served as the profession's founding moment, and historians treat its details cautiously.

TRAPS PEOPLE FALL INTO

- **Crediting D.D. with B.J.'s inventions.** Spinography, the neurocalometer and Hole in One all belong to B.J.
- **Putting osteopathy after chiropractic.** Osteopathy was announced in 1874, about two decades before the Lillard adjustment.
- **Reading Morikubo as proof that chiropractic works.** It was an acquittal on a legal argument that chiropractic was distinct from osteopathy.
- **Equating straight with making the most claims.** Objective straights use traditional vocabulary but make the fewest disease claims.
- **Confusing the two subluxations.** A medical subluxation is a partial dislocation, often a reason not to manipulate.

Chapter 9 self-test · six items

1. Who helped Palmer coin the word chiropractic, meaning done by hand?

A. Reverend Samuel Weed
B. Mabel Heath Palmer
C. Shegetaro Morikubo
D. Andrew Taylor Still

A. Reverend Samuel Weed Palmer asked his patient and friend Samuel Weed, who combined the Greek cheir and praxis.

2. What did Andrew Taylor Still emphasize, in contrast to Palmer's focus on the nerve?

A. The magnetic vital fluid
B. Innate Intelligence
C. The artery and blood flow
D. Cold and loss of body heat

C. The artery and blood flow Still taught that the rule of the artery is supreme. Palmer emphasized the nervous system.

3. Which state passed the first chiropractic licensing law, and when?

A. Iowa, in 1897
B. Kansas, in 1913
C. Louisiana, in 1974
D. California, in 1922

B. Kansas, in 1913 Kansas was first in 1913. Louisiana was last in 1974.

4. What is a medical subluxation?

A. A fixation found by motion palpation
B. A change in skin temperature on one side
C. A five part complex of tissue changes
D. A partial dislocation seen on imaging

D. A partial dislocation seen on imaging In medicine, joint surfaces are only partly in contact. It often signals instability and is a reason not to manipulate.

5. Under PART, which elements can satisfy the required finding?

A. Tissue tone or a radiograph
B. Asymmetry or abnormal motion
C. Pain or tenderness alone
D. Pain or tissue tone change

B. Asymmetry or abnormal motion Two of four elements must be present, and one must be A (asymmetry) or R (range of motion abnormality).

6. What do controlled trials show for manipulation in asthma, hypertension, colic and otitis media?

A. No benefit over sham or usual care
B. Benefit seen only in young children
C. Large benefit in most of the trials
D. Benefit equal to that for back pain

A. No benefit over sham or usual care Controlled evidence does not show benefit for these nonmusculoskeletal conditions, and manipulation should not replace medical care.

The Transformation of American Medicine

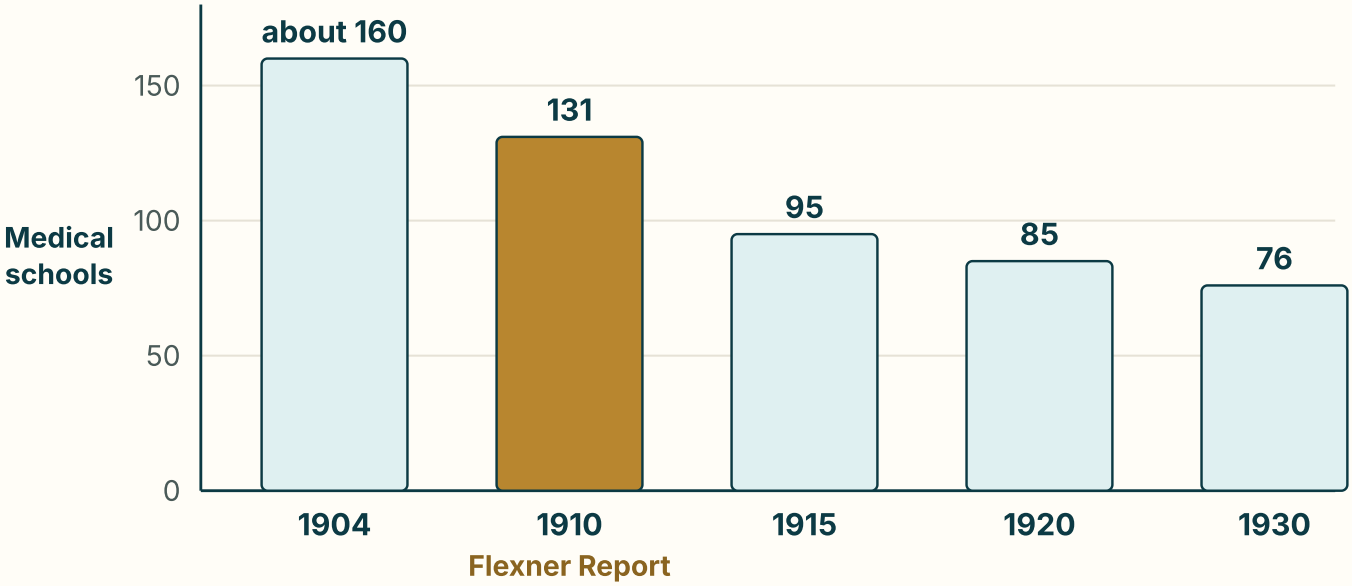
Read it in full: **Chapter 10 in the textbook**. See it in motion: **American Medicine Walkthrough** and **American Medicine Lab**.

What to know

Heroic medicine treated disease as excess with bloodletting, calomel, emetics and blistering, a legacy of humoral theory. Proprietary schools sold short lecture courses, licensing was repealed in the 1830s and 1840s, and the AMA (1847) was weak. Anesthesia, epidemiology, germ theory, antisepsis and x-rays transformed medicine later in the century.

Thomsonians (heat, lobelia), eclectics (native plants), homeopaths (like cures like, dilution), hydropaths (cold water), osteopaths (the artery), Christian Scientists (prayer), chiropractors (the nerve) and naturopaths (nature cure) competed. Homeopathy shows no effect beyond placebo. The 1910 Flexner Report (Carnegie Foundation, 155 schools) drove college prerequisites, four year science curricula and university schools; schools fell from about 160 to 76, at a cost to Black, women and rural physicians and sectarian schools.

Dent v. West Virginia (1889) upheld licensure; basic science laws and the Committee on Quackery (1963 to 1974) targeted chiropractic. Wilk v. AMA (1987, affirmed 1990) found an illegal boycott without ruling on effectiveness. Since the 1990s, the biopsychosocial model, evidence based practice, NCCIH and the opioid crisis have driven integrative care.



Approximate counts of US medical schools. 160 to 76 is a fall of about 53%.

The schools roughly halved. The decline began before 1910 as the AMA rated schools, and the Flexner Report, licensing boards and foundation money accelerated it. Quality rose, but most schools for Black and women physicians and nearly all sectarian schools closed.

LOCK THESE IN

- Humoral theory: four humors; heroic medicine depleted them (bleeding, calomel, emetics, blistering).
- AMA 1847; homeopathic society 1844 was first. Licensing repealed in the 1830s and 1840s.
- Homeopathy: like cures like; 30C = 10^{60} dilution; no effect beyond placebo.
- Flexner Report 1910: Carnegie Foundation, Abraham Flexner (an educator), 155 schools.
- Schools: about 160 (1904), 85 (1920), 76 (1930). Two of seven Black medical schools survived.
- Dent v. West Virginia 1889 upheld licensure. Basic science laws from the mid 1920s.
- Committee on Quackery 1963 to 1974; Wilk ruling 1987, affirmed 1990; not about effectiveness.
- Alternative: instead of. Complementary: along with. Integrative: coordinated under evidence and safety.

The competing systems

System	Founder and start	Core idea	Later fate
Thomsonianism	Samuel Thomson; patent 1813	Cold causes disease; heat is life	Faded by the 1850s
Eclectic medicine	Wooster Beach; 1820s to 1830s	Select what works; avoid mineral drugs	Last school closed 1939
Homeopathy	Samuel Hahnemann; 1790s (US 1820s)	Like cures like; potentized dilutions	Schools closed after 1910; no effect beyond placebo
Hydropathy	Vincent Priessnitz; 1820s (US 1840s)	Water, diet, fresh air	Hydrotherapy survives in physical medicine
Osteopathy	A.T. Still; 1874	Structural lesions obstruct blood flow	DOs are fully licensed physicians
Christian Science	Mary Baker Eddy; 1875	Illness as an error of mind; prayer	Continuing religious movement
Chiropractic	D.D. Palmer; 1895	Displaced vertebrae interfere with nerves	Licensed in all states
Naturopathy	Benedict Lust; about 1902	Natural living, healing power of nature	Licensed in a minority of states

Worked cases

CASE 10.1 · THE ARITHMETIC OF A 30C DILUTION

A homeopathic remedy is labeled 30C. How diluted is it, and could it contain even one molecule of the starting substance if you began with one mole?

STEP 1 · FIND THE TOTAL DILUTION

Each C step is 1 in 100 = 10^2. Thirty steps: $(10^2)^{30}$ = $\mathbf{10^{60}}$.

STEP 2 · COMPARE WITH ONE MOLE

A mole holds about 6×10^{23} molecules.

STEP 3 · FIND THE BREAK POINT

12C is $(10^2)^{12} = 10^{24}$. Starting from 6×10^{23} molecules, the expected number left is about 0.6, so beyond about 12C even one molecule is unlikely.

STEP 4 · APPLY IT TO 30C

The expected number at 30C is $6 \times 10^{23} \div 10^{60}$, about 6×10^{-37}: effectively none.

WHAT THE EVIDENCE SAYS

Large reviews find no reliable benefit beyond placebo. The remedies are usually harmless in themselves; the risk is delay or substitution of effective care.

CASE 10.2 · MEASURING THE FLEXNER CONSOLIDATION

There were about 160 US medical schools in 1904, 85 in 1920 and 76 in 1930. What share closed or merged by 1930, and was the Flexner Report the only cause?

STEP 1 · FIND THE DROP

160 − 76 = 84 schools.

STEP 2 · FIND THE SHARE

84 ÷ 160 = 0.525, about **53%**, so the number roughly halved.

STEP 3 · CHECK THE TIMING

The decline began before 1910 as the AMA's Class A, B and C ratings took effect; the report accelerated it.

STEP 4 · NAME THE ACTORS

State licensing boards refused graduates of low rated schools, and foundations such as the General Education Board funded the schools that met the model. The report gave a public mandate; it did not close schools by itself.

TRAPS PEOPLE FALL INTO

- **Calling Flexner a physician or the AMA the sponsor.** Flexner was an educator; the Carnegie Foundation sponsored the report, with the AMA cooperating.
- **Saying the report closed schools by itself.** It accelerated a decline already underway; licensing boards and funders enforced it.
- **Saying Wilk proved chiropractic works.** It was an antitrust ruling about a boycott; the judge did not rule on effectiveness.
- **Saying the Supreme Court decided Wilk.** The Supreme Court declined review; the appeals court affirmed in 1990.
- **Mixing up alternative and complementary.** Alternative replaces conventional care; complementary is used along with it.

Chapter 10 self-test · six items

1. What was the homeopathic law of similars?

A. The artery is supreme
B. Cold water cures
C. Heat is life
D. Like cures like

D. Like cures like Hahnemann taught that a substance producing symptoms in a healthy person can cure similar symptoms in a sick one.

2. How many medical schools did Flexner visit?

A. 255
B. 55
C. 155
D. 85

C. 155 He visited all 155 schools in the United States and Canada between 1908 and 1910.

3. Which 1889 Supreme Court case upheld state medical licensing?

A. Dent v. West Virginia
B. Wilk v. AMA (Illinois)
C. Flexner v. Carnegie
D. Morikubo v. Wisconsin

A. Dent v. West Virginia The Court held that protecting the public from ignorance and fraud was a legitimate use of the state's police power.

4. When was the AMA Committee on Quackery active?

A. 1987 to 1990
B. 1963 to 1974
C. 1910 to 1920
D. 1847 to 1857

B. 1963 to 1974 Formed in 1963 and disbanded in 1974, it regarded containing and eliminating chiropractic as its prime mission.

5. What does integrative health care emphasize?

A. Avoiding all medicines and all forms of surgery
B. Coordinated care under shared standards
C. Using any therapy a patient prefers without review
D. Replacing conventional care with natural remedies

B. Coordinated care under shared standards Integrative care brings conventional and evidence supported complementary approaches together, with attention to the whole person.

6. Which describes where osteopathic physicians stand today compared with chiropractors?

A. No license in any state since the 1960s
B. A merger with homeopathy completed in 1910
C. Full medical licensure and shared residency
D. A drugless license kept separate from medicine

C. Full medical licensure and shared residency Osteopathic schools added drugs and surgery; DOs gained unlimited licensure and shared residency accreditation with MDs.

Reading the Evidence

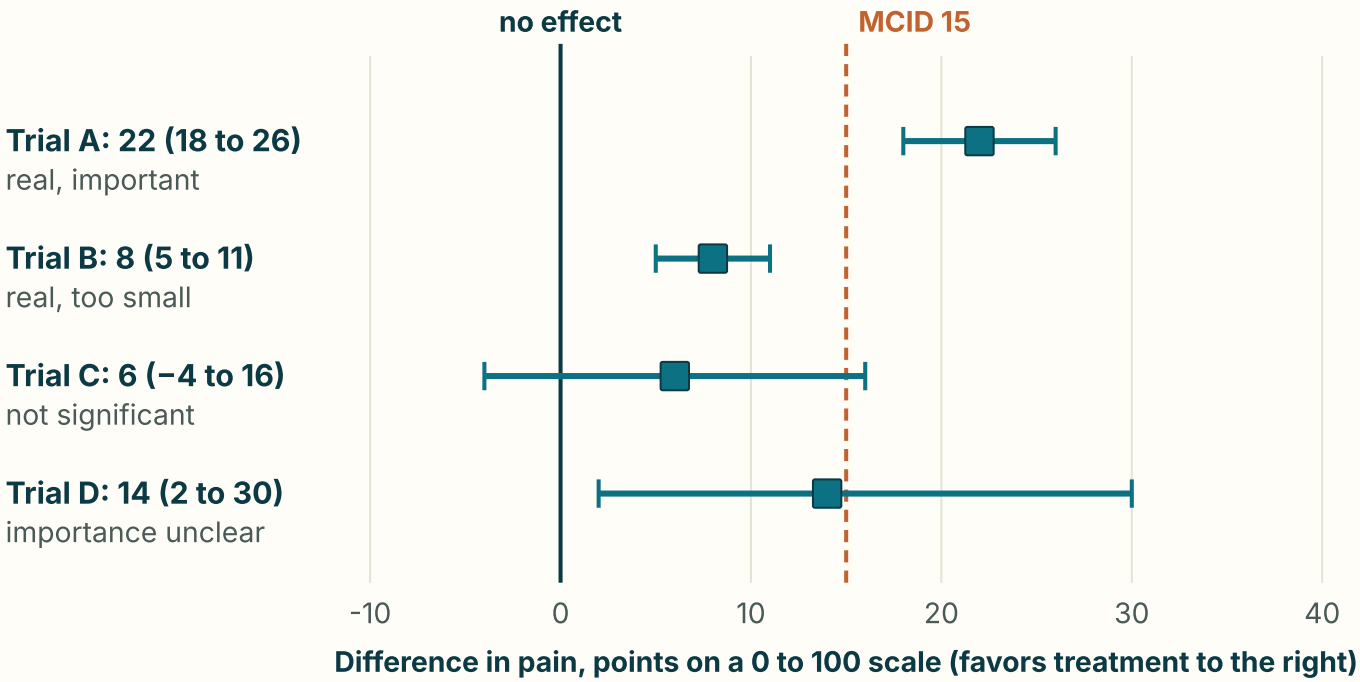
Read it in full: **Chapter 11 in the textbook**. See it in motion: **Reading the Evidence Walkthrough** and **Reading the Evidence Lab**.

What to know

Design sets how far a result can be trusted. RCTs balance known and unknown confounders; cohort, case control (odds ratio) and cross-sectional studies answer questions trials cannot, including rare harms. Bias is systematic error; allocation concealment, blinding, intention to treat and preregistration defend against it. Only randomization controls unmeasured confounders. Natural history, regression to the mean and contextual effects make any treatment look good without a control group.

NNT = 1 ÷ absolute risk difference; relative measures without baseline rates mislead. A confidence interval shows size and precision: compare it with zero for significance and with the MCID for importance. A p value is not the probability the null is true. Forest plots show each study and the pooled diamond; check heterogeneity and publication bias. GRADE rates certainty high, moderate, low or very low.

Manipulation helps low back and neck pain about as much as other recommended care, with small specific effects over sham, and is not supported for non-musculoskeletal disease. Acupuncture, yoga, tai chi and mindfulness have moderate support for particular uses; homeopathy has none beyond placebo. Apply one standard to every therapy.



Two reference lines, four verdicts. Zero tells you whether a difference is statistically significant; the minimal clinically important difference tells you whether it matters. Only interval A clears both.

LOCK THESE IN

- Experimental: investigators assign. Observational: investigators watch.
- Cohort gives relative risk; case control gives odds ratio. Cohort: cause first. Case control: cases first.
- Allocation concealment prevents selection bias; intention to treat preserves randomization.
- A confounder links to exposure and outcome; only randomization handles unmeasured ones.
- ARR = CER − EER (for harm). RRR = ARR ÷ CER. NNT = 1 ÷ ARR, rounded up.
- CI crossing 0 (or 1 for ratios) is not significant; compare the interval with the MCID.
- GRADE down: bias, inconsistency, indirectness, imprecision, publication bias. Up: large effect, dose response, confounding.
- Three verdicts: versus no treatment, versus sham, versus other recommended care.

Measures for yes or no outcomes (CER 0.40, EER 0.60)

Measure	Formula	Worked value	No effect
Absolute difference	EER − CER	0.20 (20 percentage points)	0
Relative risk	EER ÷ CER	1.5	1
Relative difference	(EER − CER) ÷ CER	0.50 (50% more)	0
Number needed to treat	1 ÷ absolute difference	5	Infinite
Odds ratio	[EER/(1 − EER)] ÷ [CER/(1 − CER)]	1.5 ÷ 0.667 = 2.25	1

Worked cases

CASE 11.1 · ARR, RRR, NNT AND THE ODDS RATIO

In a trial, 30% of control patients and 18% of treated patients develop chronic pain at one year. Find the ARR, RRR, NNT and odds ratio.

STEP 1 · FIND THE ARR

CER − EER = 0.30 − 0.18 = **0.12**, or 12 percentage points.

STEP 2 · FIND THE RRR

0.12 ÷ 0.30 = **0.40**, a 40% relative reduction.

STEP 3 · FIND THE NNT

1 ÷ 0.12 = 8.33, rounded up to **9** patients treated to prevent one case.

STEP 4 · FIND THE ODDS RATIO

Treated odds 0.18 ÷ 0.82 = 0.220; control odds 0.30 ÷ 0.70 = 0.429; OR = 0.220 ÷ 0.429 = about **0.51**.

CHECK IT

The relative risk is 0.18 ÷ 0.30 = 0.60. The OR (0.51) sits farther from 1 than the RR because the outcome is common, which is when ORs exaggerate.

CASE 11.2 · THE SAME RELATIVE EFFECT, TWO BASELINES

A treatment "reduces risk by 25%." Find the NNT when the baseline risk is 20% and when it is 2%.

STEP 1 · BASELINE 20%

ARR = 0.20 × 0.25 = 0.05. NNT = 1 ÷ 0.05 = **20**.

STEP 2 · BASELINE 2%

ARR = 0.02 × 0.25 = 0.005. NNT = 1 ÷ 0.005 = **200**.

STEP 3 · COMPARE

The same relative effect means ten times more patients treated per benefit when the outcome is rare.

THE HABIT

Turn every relative claim into an absolute difference and an NNT before deciding what it means for a patient.

TRAPS PEOPLE FALL INTO

- **Reading a p value as the chance the result is due to luck.** It is the probability of data this extreme if there were no true difference.
- **Equating significant with important.** A large trial can make a 2 point pain difference significant and meaningless.
- **Calling a nonsignificant small trial proof of no effect.** It may be underpowered. Absence of evidence is not evidence of absence.
- **Trusting a before and after story.** Natural history, regression to the mean and co-interventions can explain it.
- **Using relative risk without the baseline.** Halving 2 in 10,000 is 1 in 10,000.

Chapter 11 self-test · six items

1. Which design best balances confounders that no one thought to measure?

A. Cross-sectional survey
B. Prospective cohort study
C. Matched case control study
D. Randomized controlled trial

D. Randomized controlled trial Only randomization balances unknown confounders; adjustment handles only measured ones.

2. What is the formula for the number needed to treat?

A. 1 ÷ absolute risk difference
B. Relative risk − 1, then inverted
C. Absolute difference × 100
D. 1 ÷ relative risk reduction

A. 1 ÷ absolute risk difference The NNT is the reciprocal of the absolute difference in event rates, rounded up.

3. Which GRADE factor can raise certainty for observational evidence?

A. Wide imprecision
B. A dose response gradient
C. Serious indirectness
D. Unexplained inconsistency

B. A dose response gradient A large effect, a dose response gradient and confounding that would have shrunk the effect can upgrade observational evidence.

4. What does an I^2 of about 75% suggest in a meta-analysis?

A. A statistically significant pool
B. High certainty of evidence
C. High heterogeneity between studies
D. Low risk of publication bias

C. High heterogeneity between studies I^2 near 75% indicates high heterogeneity, a signal to ask why the studies differ.

5. What do reviews conclude about spinal manipulation for non-musculoskeletal conditions?

A. No reliable evidence of effect
B. Benefit equal to back pain
C. Moderate evidence of benefit
D. Strong evidence for asthma only

A. No reliable evidence of effect Reviews, including panels with chiropractic researchers, found no reliable evidence for asthma, hypertension, colic, otitis media or dysmenorrhea.

6. In a meta-analysis, the small imprecise studies all sit on the side favoring treatment, and the bottom left of the plot is empty. What is the likely concern?

A. Heterogeneity is zero across the studies
B. Small unfavorable studies may be missing
C. Large studies were left out of the review
D. The pooled estimate must be exactly correct

B. Small unfavorable studies may be missing Asymmetry suggests publication bias, though genuine small study differences can also cause it.

CHAPTER 12

Stress and the Autonomic Nervous System

Read it in full: **Chapter 12 in the textbook**. See it in motion: **Stress and Autonomic Balance Walkthrough** and **Stress and Autonomic Balance Lab**.

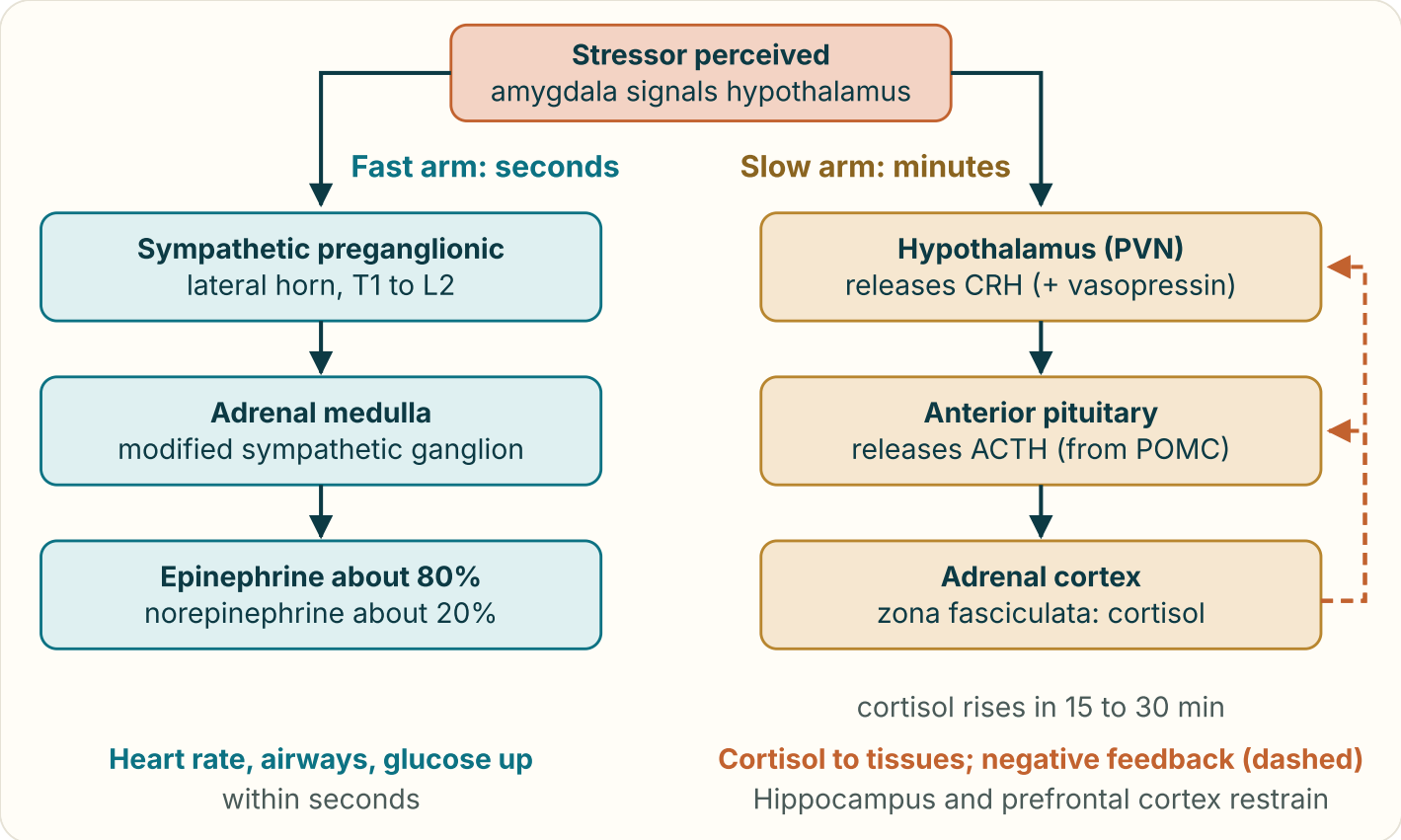
What to know

The fast sympathetic adrenal medullary arm releases epinephrine within seconds; the slow HPA axis runs CRH to ACTH to cortisol, which raises glucose, supports blood pressure, restrains

inflammation, shuts itself off by negative feedback and peaks after waking. Long term steroids suppress CRH and ACTH and weaken bone.

Sympathetic: T1 to L2, short pre and long postganglionic fibers, mostly norepinephrine (sweat glands use ACh). Parasympathetic: CN III, VII, IX, X and S2 to S4, long pre and short postganglionic fibers, ACh at muscarinic receptors. Vagal tone holds resting heart rate below the SA node's intrinsic 90 to 110; balance means flexibility. Allostatic load is the cost of repeated, unadapted, prolonged or inadequate responses; glucocorticoid resistance explains chronic inflammation.

HRV reflects adaptability: RMSSD and HF are mainly vagal, SDNN is total, and LF/HF is not a clean sympathetic index. Acute stress can cause analgesia; chronic stress promotes hyperalgesia and sensitization. Education, graded activity, exercise, sleep and psychological care break the cycle, with manual therapy as a short term aid.



Two arms, two time scales. The adrenal medulla belongs to the fast sympathetic arm and releases epinephrine within seconds; the adrenal cortex belongs to the slow HPA arm, where CRH drives ACTH and ACTH drives cortisol, which then shuts the axis off.

LOCK THESE IN

- HPA: hypothalamus CRH, pituitary ACTH, adrenal cortex (zona fasciculata) cortisol; negative feedback.
- Adrenal medulla = fast sympathetic arm, about 80% epinephrine. Adrenal cortex = slow HPA arm.
- Sympathetic T1 to L2 (thoracolumbar); parasympathetic CN III, VII, IX, X and S2 to S4 (craniosacral).
- Ganglia: nicotinic ACh. Parasympathetic targets: muscarinic ACh. Sympathetic targets: NE, except sweat glands (ACh).
- Intrinsic SA rate about 90 to 110; vagal tone brings it to 60 to 80.
- Allostatic load patterns: repeated hits, lack of adaptation, prolonged response, inadequate response.
- RMSSD, pNN50, HF: vagal. SDNN: total. LF/HF is not a sympathetic index.
- Acute danger: stress induced analgesia. Chronic stress: stress induced hyperalgesia.

Autonomic receptors and organ effects

Receptor or organ	Sympathetic	Parasympathetic
Heart	Faster, stronger (beta-1)	Slower (vagus, M2)
Bronchioles	Dilate (beta-2)	Constrict, mucus (M3)
Pupil	Dilates (alpha-1, radial muscle)	Constricts (CN III, sphincter)
Gut	Less motility; sphincters contract	More motility and secretion; sphincters relax
Bladder	Detrusor relaxes, internal sphincter contracts	Detrusor contracts (S2 to S4)
Salivary glands	Small volume, thick	Large volume, watery
Blood vessels	Constrict in skin and gut; dilate in muscle (beta-2)	Little direct effect
Sweat glands	ACh onto muscarinic receptors (exception)	None
Alpha-2 (presynaptic)	Less NE release, less insulin, lower central outflow	No parasympathetic counterpart

Worked cases

CASE 12.1 · COMPUTING RMSSD AND PNN50

Five RR intervals are recorded: 980, 910, 950, 1000 and 940 ms. Find the successive differences, RMSSD, pNN50 and mean heart rate.

STEP 1 · LIST SUCCESSIVE DIFFERENCES

910 − 980 = −70; 950 − 910 = 40; 1000 − 950 = 50; 940 − 1000 = −60 ms.

STEP 2 · SQUARE AND AVERAGE

4,900 + 1,600 + 2,500 + 3,600 = 12,600; 12,600 ÷ 4 = 3,150.

STEP 3 · TAKE THE SQUARE ROOT

RMSSD = √3,150 = about **56 ms**.

STEP 4 · COUNT PNN50

Differences larger than 50 ms: 70 and 60 (50 is not larger than 50), so 2 of 4 = **50%**.

STEP 5 · FIND HEART RATE

Mean RR = 4,780 ÷ 5 = 956 ms; 60,000 ÷ 956 = about **63 beats per minute**.

INTERPRET

One short recording means little alone. Follow one person's trend under the same conditions.

CASE 12.2 · WHY SLOW BREATHING FOOLS THE LF/HF RATIO

A user breathes at 6 breaths per minute during a relaxation exercise. The app reports a jump in LF/HF and labels her sympathetic dominant. Explain the error.

STEP 1 · CONVERT BREATHING TO FREQUENCY

6 breaths per minute ÷ 60 = **0.1 Hz**.

STEP 2 · PLACE IT IN A BAND

0.1 Hz lies in the LF band (0.04 to 0.15 Hz), not the HF band (0.15 to 0.40 Hz).

STEP 3 · NAME THE SOURCE

The oscillation is respiratory sinus arrhythmia, which is vagally mediated, now sitting in LF.

STEP 4 · CONCLUDE

LF rises, LF/HF rises, yet vagal activity is high. LF/HF is not a valid sympathetic index here; use RMSSD instead.

TRAPS PEOPLE FALL INTO

- **Putting the adrenal medulla in the HPA axis.** The medulla is the fast sympathetic arm; the cortex makes cortisol in the HPA arm.
- **Saying all sympathetic targets use norepinephrine.** Most eccrine sweat glands receive ACh onto muscarinic receptors.
- **Calling the vagus a motor nerve.** About 80% of its fibers are afferent, carrying interoception.
- **Reading LF/HF as sympathetic balance.** LF includes baroreflex and vagal activity, and slow breathing moves vagal RSA into LF.
- **Expecting chronic stress to lower inflammation.** Glucocorticoid resistance weakens cortisol's brake, so inflammation rises.

Chapter 12 self-test · six items

1. Which gland releases cortisol, and from which zone?

A. Hypothalamus, paraventricular nucleus
B. Adrenal medulla, chromaffin cells
C. Adrenal cortex, zona fasciculata
D. Anterior pituitary, corticotrophs

C. Adrenal cortex, zona fasciculata ACTH stimulates the zona fasciculata of the adrenal cortex to make cortisol.

2. When does cortisol normally peak in the day?

A. Shortly after waking
B. In the late evening
C. At midafternoon
D. Around midnight

A. Shortly after waking Cortisol is lowest near midnight and surges in the first 30 to 45 minutes after waking.

3. Which spinal segments carry parasympathetic outflow?

A. T1 to L2
B. L1 to L4
C. C5 to T1
D. S2 to S4

D. S2 to S4 The parasympathetic division is craniosacral: cranial nerves III, VII, IX and X plus S2 to S4.

4. What receptor do all autonomic preganglionic neurons act on?

A. Beta-1 adrenergic receptors
B. Nicotinic acetylcholine receptors
C. Alpha-1 adrenergic receptors
D. Muscarinic acetylcholine receptors

B. Nicotinic acetylcholine receptors All preganglionic neurons release ACh onto nicotinic receptors on the postganglionic neuron.

5. In which HRV band does breathing at 12 breaths per minute fall?

A. Low frequency
B. Ultra low frequency
C. Very low frequency
D. High frequency

D. High frequency 12 per minute is 0.2 Hz, inside the HF band of 0.15 to 0.40 Hz.

6. What does polyvagal theory represent according to the chapter?

A. A useful model whose claims are debated
B. A disproven idea of only historical interest
C. Settled and proven autonomic physiology
D. A validated measure of heart rate variability

A. A useful model whose claims are debated It offers useful clinical language, but several specific anatomical and evolutionary claims are disputed.

CHAPTER 13

Breathing, Meditation and Yoga

Read it in full: **Chapter 13 in the textbook**. See it in motion: **Breathing, Meditation and Yoga Walkthrough** and **Breathing, Meditation and Yoga Lab**.

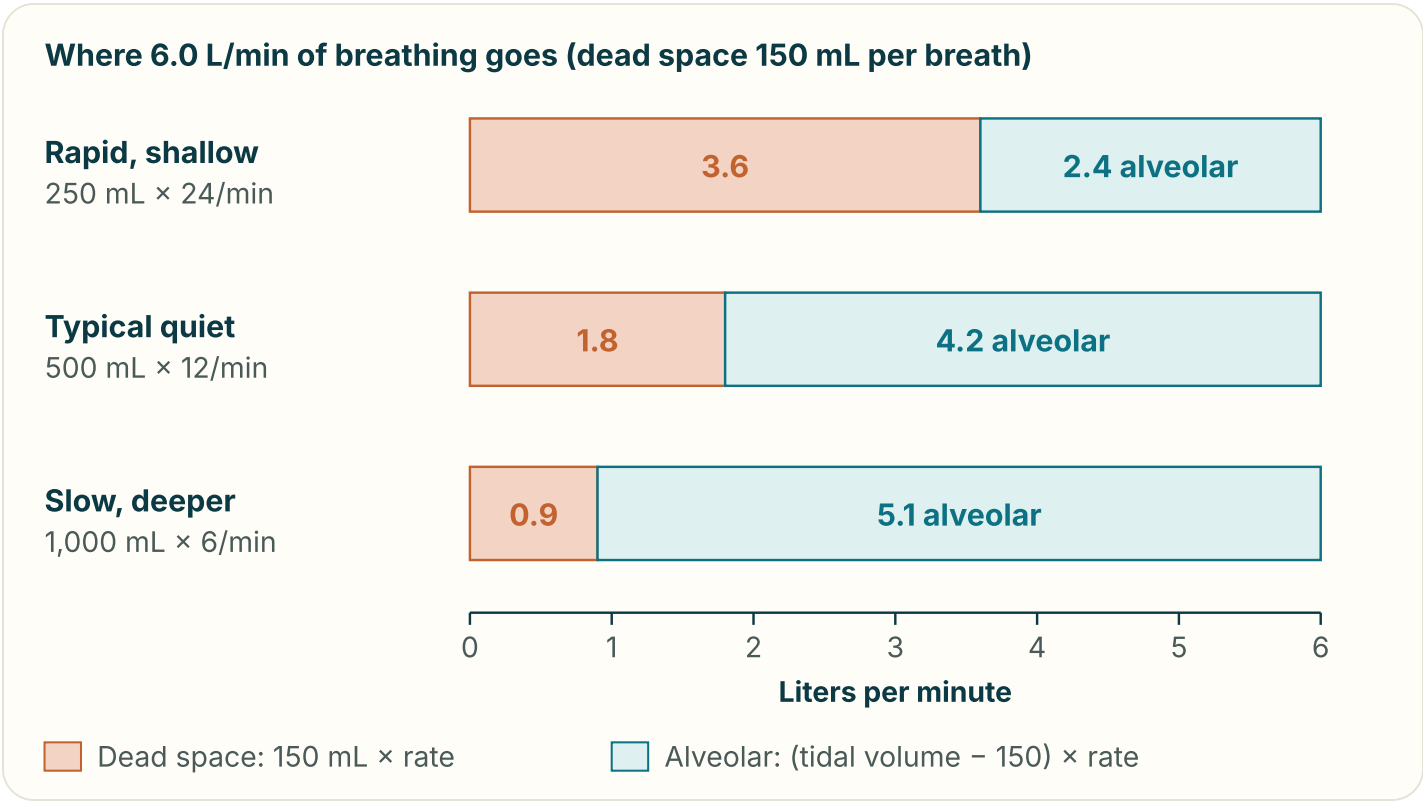
What to know

The diaphragm (phrenic nerve, C3 to C5) is the main inspiratory muscle; quiet expiration is passive. Alveolar ventilation = (tidal volume − dead space) × rate, so slow, moderately deep breathing beats rapid shallow breathing. Breathing is driven mainly by CO2; overbreathing causes respiratory alkalosis with dizziness and tingling. Retraining teaches a slow, nasal, low, quiet pattern after disease is excluded.

Mindfulness is present moment awareness without judgment; focused attention and open monitoring are the main styles. MBSR and MBCT are eight week programs; MBCT cuts depressive relapse by about a third. Meditation reduces pain unpleasantness more than intensity and is low risk for most, not all.

Yoga is a classical Indian school; asana is one of Patanjali's eight limbs. Postures load the spine through flexion, extension, rotation and axial load, so modify for osteoporosis, glaucoma, hypertension, neck problems and hypermobility. Yoga, tai chi and MBSR give modest benefits for

chronic low back pain, similar to other active care. Breathing near 6 per minute creates baroreflex resonance.



Same air in, different air to the alveoli. Every breath spends 150 mL on dead space, so 24 small breaths waste 3.6 L/min while 6 larger breaths waste only 0.9 L/min. That is why retraining targets a slower rate rather than simply deep breaths.

LOCK THESE IN

- Phrenic nerve C3, C4, C5. Quiet expiration is passive recoil.
- Alveolar ventilation = (tidal volume − 150 mL dead space) × rate.
- CO2 drives breathing; normal PaCO2 35 to 45 mmHg. Overbreathing gives respiratory alkalosis.
- Hyperventilation means ventilation exceeds metabolic need, not just fast breathing.
- Focused attention versus open monitoring. Mindfulness: on purpose, present moment, without judgment.
- MBSR: 8 weeks, body scan, sitting, gentle yoga. MBCT: relapse risk down about a third.
- Eight limbs: yama, niyama, asana, pranayama, pratyahara, dharana, dhyana, samadhi.
- Resonance: about 6 breaths per minute = 0.1 Hz, one breath per 10 second baroreflex cycle.

Breathing patterns and ventilation

Pattern	Tidal volume × rate	Minute ventilation	Alveolar ventilation
Rapid, shallow	250 mL × 24	6.0 L/min	(250 − 150) × 24 = 2.4 L/min
Typical quiet	500 mL × 12	6.0 L/min	(500 − 150) × 12 = 4.2 L/min
Slow, deeper	1,000 mL × 6	6.0 L/min	(1,000 − 150) × 6 = 5.1 L/min
Upper chest dominant	Chest and shoulders rise first	Accessory overuse	Neck and shoulder tension
Chronic overbreathing	Sighs, yawns, faster at rest	Low CO2	Dizziness, tingling, air hunger
Paradoxical	Abdomen pulls in on inhale	Inefficient diaphragm	Also seen with diaphragm weakness: evaluate

Worked cases

CASE 13.1 · ALVEOLAR VENTILATION AT THE SAME MINUTE VENTILATION

Two patients each move 8 L/min. One breathes 400 mL at 20 per minute; the other 800 mL at 10 per minute. With 150 mL of dead space, who gets more fresh air to the alveoli?

STEP 1 · CHECK MINUTE VENTILATION

400 × 20 = 8,000 mL; 800 × 10 = 8,000 mL. Both are 8.0 L/min.

STEP 2 · SUBTRACT DEAD SPACE PER BREATH

400 − 150 = 250 mL; 800 − 150 = 650 mL.

STEP 3 · MULTIPLY BY RATE

250 × 20 = **5.0 L/min**; 650 × 10 = **6.5 L/min**.

STEP 4 · INTERPRET

The slower breather gets 1.5 L/min more alveolar ventilation, because dead space wastes a larger share of small breaths. Retraining targets a slower rate, not maximal breaths.

CASE 13.2 · WHY 6 BREATHS PER MINUTE IS SPECIAL

Explain, with numbers, why slow paced breathing at about 6 per minute produces the largest heart rate oscillations.

STEP 1 · FIND THE BAROREFLEX RHYTHM

Because of its delay, the baroreflex makes heart rate and pressure oscillate at about 0.1 Hz, one cycle every 10 seconds.

STEP 2 · MATCH THE BREATH

60 seconds ÷ 10 seconds = **6 breaths per minute**, which is 0.1 Hz.

STEP 3 · COMBINE THE RHYTHMS

Heart rate rises on inhale and falls on exhale (respiratory sinus arrhythmia). At 6 per minute these swings line up with the baroreflex wave and reinforce it: resonance.

STEP 4 · APPLY IT

HRV biofeedback trains people to find their own resonance, usually 4.5 to 7 per minute. Benefits for stress and anxiety are real but modest, and much may come from relaxation and attention.

TRAPS PEOPLE FALL INTO

- **Defining hyperventilation as fast breathing.** It means ventilation in excess of metabolic need, so PaCO2 falls. A sprinter can breathe fast with normal CO2.
- **Telling everyone to take big deep breaths.** Very large breaths raise the work of breathing and wash out CO2. Retraining targets a slower rate.
- **Equating mindfulness with relaxation.** Mindfulness is nonjudging awareness; a person can be mindful while tense or in pain.
- **Calling asana the heart of classical yoga.** It is one of eight limbs; classical yoga was mainly a discipline of mind and ethics.
- **Prescribing breathing exercises for new exertional breathlessness.** Rule out heart and lung disease first; refer for evaluation.

Chapter 13 self-test · six items

1. Which muscle is the main muscle of inspiration?

A. Internal intercostals
B. Sternocleidomastoid
C. Scalenes
D. Diaphragm

D. Diaphragm The diaphragm flattens and descends to enlarge the chest. The scalenes help, and internal intercostals assist forced expiration.

2. About how much of each breath fills the anatomic dead space in an adult?

A. About 1,000 mL
B. About 150 mL
C. About 50 mL
D. About 500 mL

B. About 150 mL About 150 mL fills the conducting airways where no gas exchange happens.

3. What is MBCT mainly designed to do?

A. Prevent relapse of depression
B. Cure an acute psychosis
C. Treat chronic asthma attacks
D. Lower blood cholesterol

A. Prevent relapse of depression MBCT combines mindfulness with cognitive therapy to reduce relapse in people with recurrent depression.

4. Mindfulness tends to reduce which aspect of pain more?

A. Its body location
B. Its total duration
C. Its unpleasantness
D. Its raw intensity

C. Its unpleasantness Laboratory studies suggest mindfulness changes how the brain appraises sensation, easing unpleasantness more than intensity.

5. Which postures should a person with glaucoma usually avoid?

A. Seated chair poses
B. Head down inversions
C. Supported bridge pose
D. Gentle seated twists

B. Head down inversions Inversions such as headstand raise intraocular pressure, so glaucoma patients are usually advised to avoid them.

6. Which practice has good evidence for reducing falls in older adults?

A. Hot yoga
B. Pranayama
C. Tai chi
D. Sauna use

C. Tai chi Tai chi has moderate to high certainty evidence for reducing falls and is included in fall prevention programs.

Traditional Systems and Nature Therapy

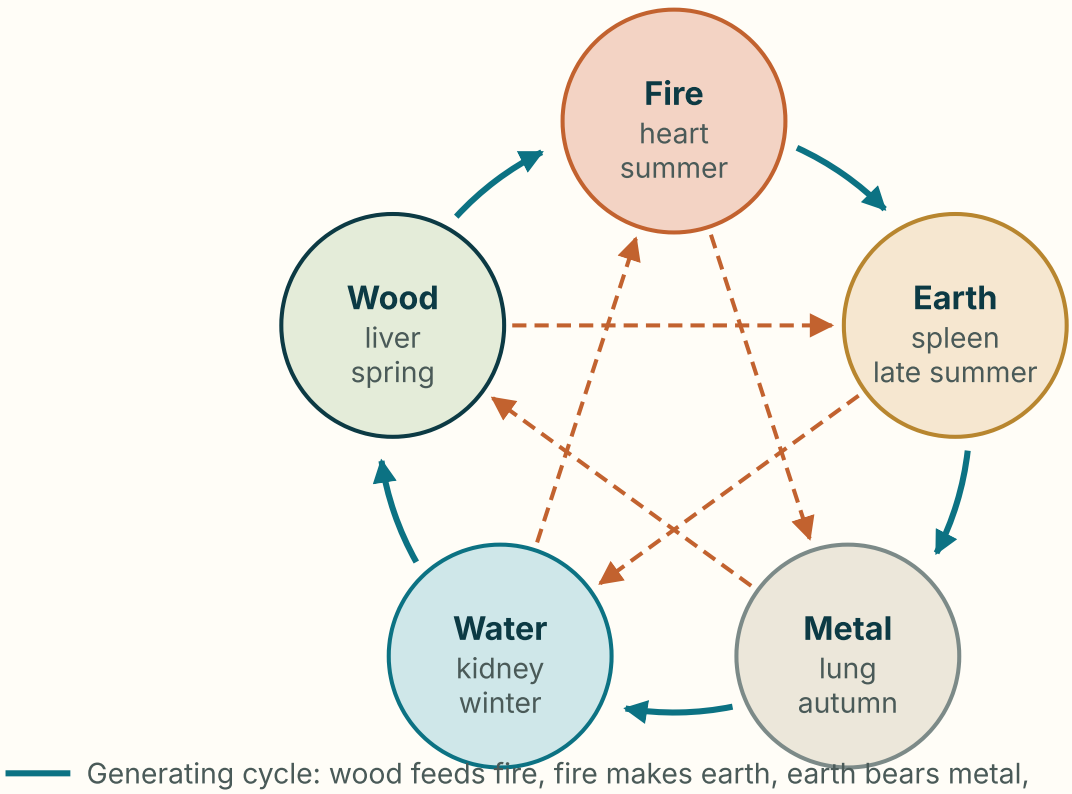
Read it in full: **Chapter 14 in the textbook**. See it in motion: **Traditional Systems Walkthrough** and **Traditional Systems Lab**.

What to know

TCM explains health through qi, yin and yang, the five phases and meridians, and diagnoses patterns through four examinations. Acupuncture beats usual care modestly for chronic pain but beats sham only slightly, pointing to large contextual effects; with sterile needles it is safe, and pneumothorax is the main serious risk. Chinese herbs carry risks such as aristolochic acid and ephedra, yet also gave us artemisinin.

Ayurveda describes three doshas built from five elements: vata (space and air, movement), pitta (fire and water, transformation) and kapha (earth and water, structure); prakriti is the constitution. About one in five tested Ayurvedic products contained lead, mercury or arsenic. Naturopathy grew from nature cure; licensed NDs differ from unlicensed naturopaths, and homeopathy lacks evidence.

Many drugs come from plants, but US supplements need no proof of safety or efficacy and may be mislabeled. St. John's wort induces CYP3A4 and P-glycoprotein and lowers other drug levels; ginkgo and garlic add bleeding risk. Forest bathing lowers short term stress markers. Weigh evidence and safety together, consider indirect harms and ask every patient about supplements.



Two cycles among five phases. Around the outside each phase nourishes the next; across the inside each phase restrains another. A common question: water restrains fire, and fire restrains metal.

LOCK THESE IN

- Generating cycle: wood, fire, earth, metal, water. Controlling: wood restrains earth, earth dams water, water quenches fire, fire melts metal, metal cuts wood.
- Acupuncture: moderate benefit versus usual care, small versus sham. Main serious risk: pneumothorax.
- Aristolochic acid: kidney failure and urothelial cancer. Ephedra banned 2004. Artemisinin: a Nobel Prize.
- Vata = space + air (moves); pitta = fire + water (transforms); kapha = earth + water (holds).
- About one in five Ayurvedic products contained lead, mercury or arsenic.
- Licensed ND: four year graduate program, boards, licensed in about half of states.
- Supplements (1994 law): no premarket proof; structure and function claims only.
- St. John's wort induces CYP3A4 and P-glycoprotein: lower cyclosporine, contraceptive, warfarin levels.

Traditional systems at a glance

Item	Core idea	Evidence or safety
Qi	Vital energy; illness is deficiency, excess or stagnation	No measurable substance found
Acupuncture	Needling points along meridians; de qi	Small specific effect over sham; pneumothorax risk
Chinese herbs	Multi ingredient formulas	Aristolochia, ephedra, contamination; artemisinin
Vata	Space and air; movement	Excess: anxiety, insomnia, dry skin, constipation, stiffness
Pitta	Fire and water; transformation	Excess: inflammation, heartburn, rashes, irritability
Kapha	Earth and water; structure	Excess: congestion, weight gain, lethargy
Rasa shastra	Medicines with metals as bhasmas	Lead, mercury, arsenic poisoning
Naturopathy	Healing power of nature; treat the cause	Licensed ND versus unlicensed; homeopathy unsupported
Forest bathing	Slow sensory immersion in nature	Short term stress markers down; confounding in cohorts

Worked cases

CASE 14.1 · READING AN ACUPUNCTURE TRIAL

A large trial in chronic low back pain reports responders at six months: real acupuncture about 48%, sham acupuncture about 44%, conventional care about 27%. Find the absolute differences and NNTs and interpret them.

STEP 1 · REAL VERSUS CONVENTIONAL CARE

0.48 − 0.27 = 0.21. NNT = 1 ÷ 0.21 = 4.8, rounded up to **5**.

STEP 2 · REAL VERSUS SHAM

0.48 − 0.44 = 0.04. NNT = 1 ÷ 0.04 = **25**.

STEP 3 · INTERPRET

Both needling procedures beat conventional care clearly, so patients benefit. Exact point location adds little, which suggests much of the effect comes from needling in general and from contextual factors.

HOLD BOTH VIEWS

Skeptics note the theory of points is not supported; supporters note the overall benefit is similar to other accepted care. Both observations can be true.

CASE 14.2 · A SUSPECTED HERB DRUG INTERACTION

A kidney transplant recipient on cyclosporine starts St. John's wort for low mood. Weeks later, signs of rejection appear. Walk through the reasoning.

STEP 1 · NAME THE HERB'S ACTION

St. John's wort is an **inducer** of CYP3A4 and P-glycoprotein.

STEP 2 · TRACE THE DRUG

Cyclosporine depends on these pathways, so it is cleared faster over days to weeks.

STEP 3 · PREDICT THE EFFECT

Blood levels fall below the effective range and the immune system attacks the graft.

STEP 4 · ACT AND PREVENT

Coordinate with the transplant team, stop the herb under supervision and check levels. Ask every patient about supplements; inducers lower drug levels, inhibitors such as goldenseal raise them.

TRAPS PEOPLE FALL INTO

- **Putting water in only one dosha.** Water belongs to both pitta and kapha.
- **Reading better than usual care as better than sham.** Acupuncture beats usual care moderately but sham only slightly.
- **Assuming natural means safe.** Foxglove, poppy, nightshade and autumn crocus are poisonous; aristolochic acid destroys kidneys.
- **Reading a structure and function claim as proof.** Supplements need no premarket proof of efficacy or safety.
- **Mixing up inducers and inhibitors.** St. John's wort induces and lowers drug levels; goldenseal inhibits and raises them.

Chapter 14 self-test · six items

1. In TCM, what is qi?

A. A type of acupuncture needle
B. Vital energy or vital breath
C. A single measurable hormone
D. The anatomical spleen

B. Vital energy or vital breath Qi is said to animate, warm, hold and defend the body and to flow through the meridians.

2. Which drug was isolated from sweet wormwood after study of classical Chinese texts?

A. Paclitaxel
B. Colchicine
C. Digoxin
D. Artemisinin

D. Artemisinin Artemisinin, an antimalarial, came from qinghao and was honored with a Nobel Prize.

3. Which elements make up the vata dosha?

A. Fire and earth
B. Earth and water
C. Space and air
D. Fire and water

C. Space and air Vata is space and air and governs movement.

4. Under the 1994 US law, what must a supplement maker prove before sale?

A. Neither safety nor efficacy
B. Safety but not efficacy
C. Both safety and efficacy data
D. Efficacy but not safety

A. Neither safety nor efficacy Supplements reach the market without required proof of safety or efficacy; new ingredients need only a notification.

5. What does St. John's wort do to cyclosporine levels?

A. Raises them through the kidneys
B. Raises them through enzyme inhibition
C. Lowers them through enzyme induction
D. Has no effect on them at all

C. Lowers them through enzyme induction It induces CYP3A4 and P-glycoprotein, speeding clearance of cyclosporine and risking transplant rejection.

6. What does attention restoration theory say nature provides?

A. Electrons absorbed through bare skin
B. Soft fascination that rests attention
C. Phytoncides that boost the immune cells
D. A fast fear response to signs of danger

B. Soft fascination that rests attention Effortless interest in clouds, leaves and water lets fatigued directed attention recover.

Cram sheet

Every number, formula and rule from the course, grouped by study guide. Cover the right columns and see if you can rebuild each row.

Chapters 1 and 2: numbers to know

Item	Value	Note
Vertebral counts	7 C, 12 T, 5 L, 5 fused S, usually 4 coccygeal	33 at birth; about 24 movable above the sacrum
Discs	23; first at C2 to C3	About a quarter of column height; 1 to 2 cm taller in the morning
Nucleus water	70 to 90% in a young adult	Held by proteoglycans such as aggrecan
Annulus	15 to 25 lamellae, fibers 60 to 65 degrees from vertical	Alternating direction; thinner behind
Curves	Thoracic kyphosis about 20 to 45; lumbar lordosis about 40 to 60 degrees	A finding, not a diagnosis
Sacral base angle	About 30 to 40 degrees standing	Steeper sacrum, deeper lordosis
Cord and sac	Conus near L1 to L2 (L3 at birth); sac ends near S2	31 pairs of spinal nerves
C1 to C2 rotation	About 40 degrees each way	About half of all neck rotation
Lumbar rotation	1 to 2 degrees per segment	About 10 degrees each way in all
Disc to body height	2:5 cervical, 1:5 thoracic, 1:3 lumbar	Taller disc, more motion
Facet load share	About 10 to 20% standing	Rises with extension, creep, degeneration
Wilke disc pressure	Lying 0.1; sitting 0.46; standing 0.5; bent forward 1.1; lifts 1.7 and 2.3 MPa	Single subject; illustrative
Buckling load	Isolated thoracolumbar about 20 N; lumbar about 90 N	Muscles make the difference
Cervical instability signs	Over about 3.5 mm translation or 11 degrees angulation	On flexion and extension films

Item	Value	Note
Lifting limits	Action limit about 3,400 N; about 6,400 N intolerable	At L5 to S1
Extensor moment arm	About 5 to 6 cm	Load arms are far longer

Chapters 1 and 2: equations and rules

Name	Rule	Units or note
Weight	1 kg weighs about 10 N	N
Moment	Force × perpendicular distance from the axis	N·m
Extensor force	Total flexion moment ÷ extensor moment arm	N
Compression estimate	Extensor force + body weight above the disc	N; ignores co-contraction
Ligament rule	A ligament limits the motion that pulls its ends apart	ALL: extension; the rest: flexion
Nerve exit rule	C1 to C7 above their vertebra; C8 at C7 to T1; T1 down below	31 pairs
Root rule	Posterolateral hits the traversing root; far lateral hits the exiting root	L4 to L5: L5 versus L4
Cervical coupling	Side bend and rotation to the same side below C2	Spinous processes toward the convexity

Chapters 3 and 4: numbers to know

Item	Value	Note
Cartilage	1 to 4 mm (up to about 6 mm in the knee); 65 to 80% water	Avascular, aneural
Friction	Coefficient about 0.001 to 0.01	Lower than ice on ice
Synovial fluid	Knee about 1 to 4 mL; under about 200 white cells per µL	Lumbar facet about 1 to 1.5 mL
Meniscoids	Fibroadipose folds up to about 5 mm	Rims, fat pads, fibroadipose types
Kaltenborn grades	0 ankylosed; 1 to 2 hypo; 3 normal; 4 to 5 hyper; 6 unstable	Joint play scale
Palpation reliability	Motion and position kappa often below 0.4	Pain provocation fair to good
Refractory period	About 20 to 30 minutes	Gas redissolves
Inflammatory phase	Peaks 1 to 3 days; settles by day 5 to 7	Neutrophils 24 to 48 h; macrophages by 48 to 72 h
Proliferative phase	About day 3 to 3 to 6 weeks	Type III collagen
Remodeling phase	About 3 weeks to 12 months or more	Type I collagen
Skin scar strength	About 20% at 3 weeks; 70 to 80% at a year	Rarely full strength
Bone loss in disuse	About 1 to 2% per month	Bed rest or spaceflight
Thrust duration	About 100 to 200 ms in the spine	Instrument under about 5 ms
Peak force	Cervical 100 to 150 N; thoracic 250 to 550 N; lumbar 200 to 500 N	Mobilization 50 to 150 N
Spindle peak response	Thrusts of about 75 to 150 ms	Animal recordings
Mild reactions	About 30 to 60% of patients	Start within 24 h, resolve in 24 to 72 h

Chapters 3 and 4: equations and scales

Name	Rule	Units or note
Rate of force application	(Peak force − preload) ÷ time to peak	N/s
Impulse	Force × time (area under the curve)	N·s
Average force from impulse	Impulse ÷ time	N
Weight	100 N is about 10 kg	N
Maitland I to V	I small early; II large to resistance; III large into resistance; IV small at limit; V thrust	Grades of range
Barrier order	Physiological, elastic, paraphysiological space, anatomical	Restrictive comes early
Convex concave rule	Convex moves: opposite. Concave moves: same.	Roll and glide

Chapters 5 and 6: levels and numbers to know

Item	Value	Note
Spinal nerves	31 pairs: 8 C, 12 T, 5 L, 5 S, 1 Co	C8 exits between C7 and T1
Plexuses	Cervical C1 to C4; brachial C5 to T1; lumbar L1 to L4; sacral L4 to S4	Formed by ventral rami
White rami	T1 to L2 only	Gray rami reach every spinal nerve
Trunk anchors	Nipple T4; xiphoid T6; umbilicus T10; inguinal ligament T12 to L1	C4 sits next to T2
Hand anchors	C6 thumb; C7 middle finger; C8 little finger	T1 medial antecubital fossa
Leg anchors	L3 medial knee; L4 medial malleolus; L5 dorsum and big toe; S1 lateral heel	S3 to S5 saddle
Reflexes	Biceps C5; brachioradialis C6; triceps C7; patellar L4; Achilles S1	Medial hamstring L5, unreliable
Reflex grades	0, 1+, 2+ normal, 3+, 4+ with clonus	Asymmetry matters most
MRC strength	0 none to 5 normal; 3 = against gravity	Most root weakness is grade 4
Lumbar herniation levels	90 to 95% at L4 to L5 or L5 to S1	C7, then C6, in the neck
SLR	Positive at about 30 to 70 degrees; sensitivity about 0.9	Crossed SLR specific
Natural history	Most improve in 6 to 12 weeks	Extruded fragments most likely to regress
EMG timing	Denervation after about 2 to 3 weeks	SNAPs normal in radiculopathy
Entrapment pressure	About 20 to 30 mmHg slows venous outflow	Axon regrowth about 1 mm a day
Fiber speeds	Aβ 35 to 75; Aδ 5 to 30; C 0.5 to 2 m/s	TRPV1 heat above about 43°C

Item	Value	Note
Chronic pain	Over 3 months; about 1 in 5 US adults	High impact about 7 to 8%
Imaging without pain	Degeneration 37% at 20 to 96% at 80; bulge 30% to 84%	Normal age changes

Chapters 7 and 8: numbers to know

Item	Value	Note
Triage shares	Serious about 1%; radicular 5 to 10%; nonspecific about 90%	Primary care low back pain
Morning stiffness	Over 30 minutes suggests inflammatory disease	Spondyloarthritis onset before 45
LR thresholds	LR+ over 10 or LR− under 0.1 decisive; 0.5 to 2 barely helps	Combine with pretest probability
SLR	Sensitivity about 0.9, specificity about 0.25	Crossed SLR about 0.3 and 0.9
Cancer history	LR+ about 7 to 15	Strongest single red flag
Fracture flags	Age over 70, long term steroids, trauma, contusion	Osteoporotic fracture most common serious finding
Canadian C-spine	High risk: age 65 or more, dangerous mechanism, limb tingling	Active rotation 45 degrees each way
Scoliosis	Cobb 10 degrees or more; AIS 2 to 3% of adolescents	Scoliometer about 7 degrees to refer
Leg length	Over about 20 mm may matter	A few mm is almost universal
Gait phases	Stance about 60%; swing 40%; double support about 10% twice	Knee peaks at about 60 degrees in initial swing
Gait norms	Speed 1.2 to 1.4 m/s; cadence 100 to 120; step 0.6 to 0.8 m; width 5 to 13 cm	Center of mass rises 4 to 5 cm
Gait speed risk	Below 0.6 dependence; below 0.8 limited; 1.0 or more independent	Street crossing about 1.2 m/s
TUG	10 s or less typical; 12 s or more fall risk	Berg under about 45 of 56
Joint position error	Over about 4.5 degrees	Common after whiplash
Disc pressure (MPa)	Lying 0.10; sitting 0.46; standing 0.50; upright sitting 0.55; bent 1.10; lifts 1.70 and 2.30	One volunteer

Item	Value	Note
Lifting equation	Load constant 23 kg	Reduced for distance, height, twist, frequency
Activity guideline	150 to 300 min moderate or 75 to 150 vigorous a week	Strength on 2 or more days

Chapters 7 and 8: equations

Name	Formula	Use
Sensitivity	a / (a + c)	Rule out when high (SnNout)
Specificity	d / (b + d)	Rule in when high (SpPin)
LR+	sensitivity / (1 − specificity)	Effect of a positive result
LR−	(1 − sensitivity) / specificity	Effect of a negative result
Odds	p / (1 − p); posttest odds = pretest odds × LR	Then p = odds / (1 + odds)
Gait speed	Step length × cadence	Convert m/min to m/s by dividing by 60

Chapters 9 and 10: dates and people

Date	Event	Who or what
1790s	Homeopathy begins	Samuel Hahnemann
1813	Thomsonian patent	Samuel Thomson
1844 / 1847	First national medical association / AMA	Homeopaths / regular physicians
1874 / 1892	Osteopathy announced / Kirksville school	A.T. Still
1875	*Science and Health*	Mary Baker Eddy
1889	Dent v. West Virginia	State licensing upheld
1895	Lillard adjustment; x-rays	D.D. Palmer; Roentgen
1897	First chiropractic school	Davenport, Iowa
About 1902	Naturopathy named	Benedict Lust
1906	Pure Food and Drug Act; UCA	Federal labeling; legal defense fund
1907	Morikubo acquitted	La Crosse, Wisconsin; attorney Tom Morris
1910	Flexner Report; spinography; *The Chiropractor's Adjuster*	Carnegie Foundation; B.J.; D.D.
1913	Kansas license; D.D. dies	First chiropractic licensing law
1924 / 1926	Neurocalometer / ICA	B.J. Palmer
1930 / 1963	NCA / renamed ACA	Broad scope tradition
1957 / 1963 to 1974	Principle 3 / Committee on Quackery	AMA
1972 / 1974	Medicare coverage / Louisiana and CCE	Last state; accreditation
1984	Reform association	Rejects subluxation as disease cause
1987 / 1990	Wilk ruling / affirmed	Judge Susan Getzendanner

Date	Event	Who or what
1991 / 2014	Office of Alternative Medicine / NCCIH	NIH
1993	About a third of adults use unconventional therapy	National survey
1994	AHCPR acute low back guideline	Manipulation listed; bed rest discouraged

Chapters 9 and 10: numbers and rules

Item	Value or rule	Note
Palmer's claim	About 95% of disease from displaced vertebrae	Not supported
Root in the IVF	About a third to a half of the foramen	1973 cadaver study
PART	Two of four; one must be A or R	Medicare documentation
Subluxation reliability	Kappa often below 0.4	Pain provocation better
US chiropractors	About 70,000; about 1 in 10 adults visits yearly	Low back pain most common
DC training	At least 90 semester hours, then about 4 years, about 4,200 hours	CCE accredited
Acute LBP effect	About 1 point on a 10 point scale	2017 meta-analysis
30C dilution	10^{60}; beyond about 12C no molecule likely	Avogadro about 6×10^{23}
Schools	About 160 (1904), 131 (1910), 95 (1915), 85 (1920), 76 (1930)	Roughly halved
Black medical schools	Two of seven survived	AMA apology 2008
Civil War	About two thirds of deaths from disease	Before germ theory took hold
Herb interactions	St. John's wort induces CYP3A4; ginkgo, fish oil add bleeding risk	Ask every patient

Chapters 11 and 12: equations

Name	Formula	Note
Absolute risk reduction	CER − EER (harm) or EER − CER (benefit)	Percentage points
Relative risk	EER ÷ CER	No effect = 1
Relative risk reduction	(CER − EER) ÷ CER	Sounds bigger than ARR
NNT	1 ÷ absolute difference, rounded up	Carries baseline risk inside it
Odds	p ÷ (1 − p)	0.60 is odds of 1.5
Odds ratio	Odds treated ÷ odds control	Approximates RR under about 10%
Power	1 − beta	Usually 80 or 90%
RMSSD	√[mean of squared successive RR differences]	Vagal, short recordings
Heart rate from RR	60,000 ÷ mean RR in ms	Beats per minute
Breathing frequency	Breaths per minute ÷ 60	12/min = 0.2 Hz (HF); 6/min = 0.1 Hz (LF)

Chapters 11 and 12: numbers to know

Item	Value	Note
Effect sizes	SMD 0.2 small, 0.5 moderate, 0.8 large	Conventions
MCID	Pain about 2 of 10 or 30%; Oswestry about 10; Roland Morris 2 to 5	Guides, not laws
Alpha	0.05	20 tests give about one false positive
Loss to follow up	Over about 20% raises concern	Attrition bias
I^2	25 low, 50 moderate, 75 high	Heterogeneity
SMT acute LBP	About 10 points on a 100 point scale	Moderate certainty
Adrenal medulla	About 80% epinephrine, 20% norepinephrine	Seconds
Cortisol	Rises in 15 to 30 min; peaks about 30 min	Awakening response about 50% in 30 to 45 min
SA node	Intrinsic 90 to 110; resting 60 to 80	Vagal tone
Vagus	About 75% of parasympathetic fibers; about 80% afferent	Interoception
SDNN (24 h)	Below 50 ms reduced; above 100 ms healthy	After MI, low SDNN raised mortality
HRV bands	HF 0.15 to 0.40; LF 0.04 to 0.15; VLF 0.0033 to 0.04; ULF below 0.0033 Hz	Resonance breathing about 6 per minute
ACE study	Four or more categories markedly raise risk	Dose response; observational

Chapters 13 and 14: numbers and equations

Item	Value or formula	Note
Phrenic nerve	C3, C4, C5	Injury below C5 usually spares the diaphragm
Diaphragm descent	1 to 2 cm quiet; up to 10 cm maximal	Crura: right L1 to L3, left L1 and L2
Tidal volume and dead space	About 500 mL; about 150 mL	12 to 16 breaths/min; 6 to 8 L/min
Alveolar ventilation	(Tidal volume − 150 mL) × rate	250 × 24 gives 2.4; 1,000 × 6 gives 5.1 L/min
PaCO2	35 to 45 mmHg (40 textbook)	CO2 sets the drive at sea level
Slow paced breathing	About 5 to 7 per minute; resonance about 6	0.1 Hz = one breath per 10 s
Individual resonance	4.5 to 7 breaths per minute	HRV biofeedback
MBSR	8 weeks; 2 to 2.5 h sessions; about 45 min daily; one day retreat	Body scan, sitting, gentle yoga
MBCT	Relapse risk down about a third over 60 weeks	Best with 3 or more prior episodes
Hot yoga	About 40°C (105°F)	Heat illness
Acupuncture points	About 361 on the main channels	Twelve principal meridians
Acupuncture trial	Real about 48%, sham 44%, conventional 27% responders	NNT 5 versus usual care, 25 versus sham
Acupuncture IPD meta-analysis	About 20,000 patients	Small effect versus sham
Ayurvedic products	About 1 in 5 contained lead, mercury or arsenic	Test blood lead
Ephedra	Banned in US supplements in 2004	Strokes, heart attacks, deaths

Item	Value or formula	Note
Supplement law	1994; no premarket proof of safety or efficacy	Structure and function claims only
Forest bathing	Named 1982 in Japan; about 2 hour sessions	About 120 min a week in nature linked to well being

Chapters 13 and 14: systems, herbs and interactions

Item	Key fact	Watch for
Eight limbs	Yama, niyama, asana, pranayama, pratyahara, dharana, dhyana, samadhi	Asana is third
Fast pranayama	Kapalabhati, bhastrika	Pregnancy, hypertension, epilepsy, hernia, glaucoma
Five phases	Generating: wood, fire, earth, metal, water	Controlling: water quenches fire, fire melts metal
Doshas	Vata space and air; pitta fire and water; kapha earth and water	Water in two doshas
Naturopathy principles	Vis medicatrix naturae, tolle causam, primum non nocere, docere, whole person, prevention	Licensed ND versus unlicensed
Plant drugs	Aspirin, digoxin, morphine, quinine, artemisinin, atropine, metformin, paclitaxel, vincristine, colchicine	Natural can be toxic
St. John's wort	Induces CYP3A4 and P-glycoprotein	Cyclosporine, contraceptives, warfarin, HIV drugs; serotonin syndrome
Bleeding risk	Ginkgo, garlic, fish oil, high dose turmeric	Anticoagulants, surgery
Liver injury	Kava, green tea extract, comfrey, ashwagandha and turmeric (rare)	Ask about supplements
Licorice	Hypertension, low potassium	Blocks cortisol inactivation

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