

Mechatronische Systeme in der Medizin

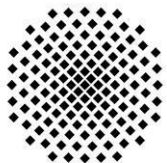
Sommersem. 2026

Prüfungsskript

Prof. Dr. med. Urs Schneider



Prothetik



Universität Stuttgart



*Stuttgart Minneapolis
Rehab Research*



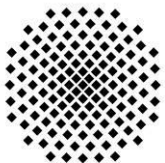
*A Fraunhofer IPA and Minneapolis Veteran Affairs
Medical Center Cooperation*

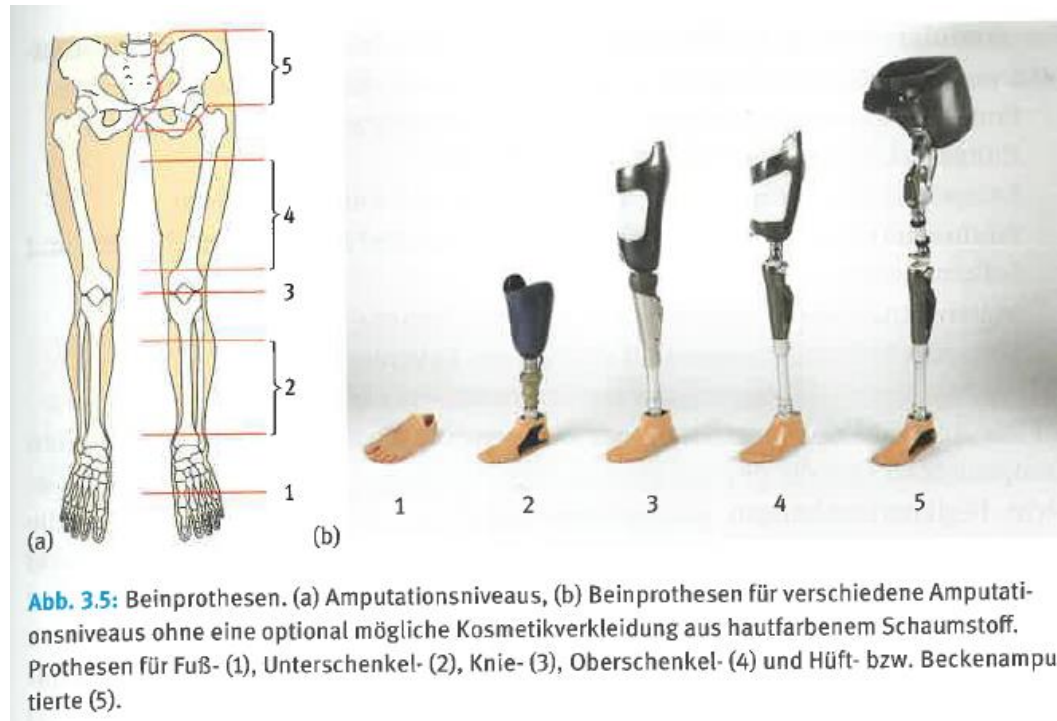
Einführung in die Prothetik

Begriffsdefinition Prothese

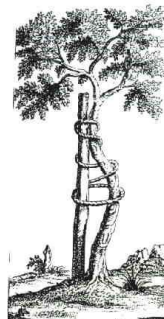
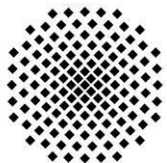
Eine **Prothese** (von altgriechisch: *πρό* (*pro*) „vor, anstatt“ und *θέσις* (*thesis*) „das Setzen, Stellen“) bezeichnet in der Medizin den Ersatz von Gliedmaßen, Organen oder Organteilen durch künstlich geschaffene, funktionell ähnliche Produkte.

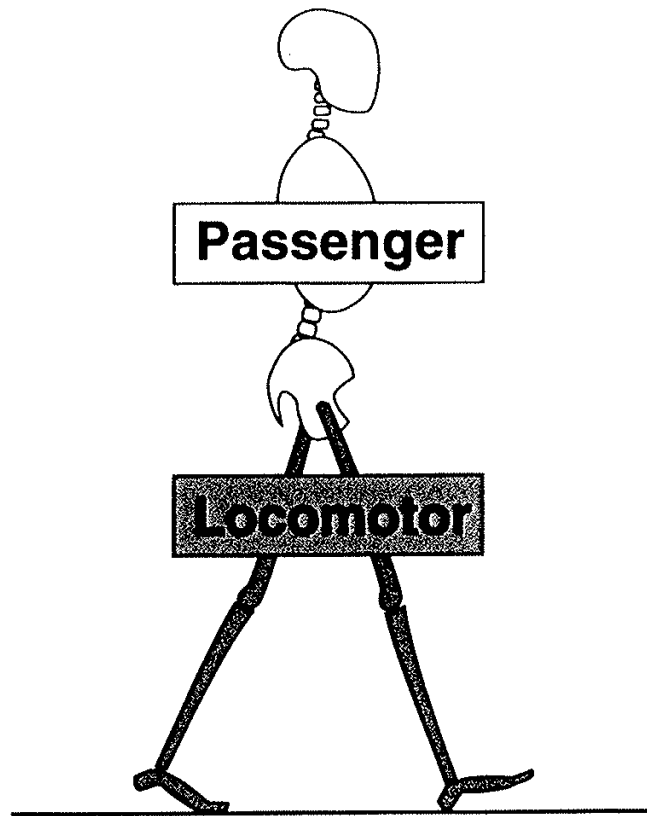
Befindet sich die Prothese außerhalb des Körpers, spricht man von einer **Exoprothese** (wie z. B. bei künstlichen Gliedmaßen, Arm-, Bein- oder Handprothese), andernfalls von einer **Endoprothese** oder einem Implantat.





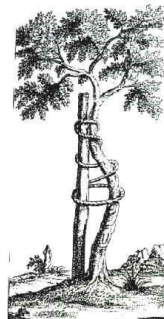
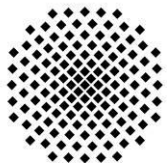
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Gruyter 2015





Perry, Gait Analysis, 1992

Figure 3.1 Functional division of the body. During walking, the upper body is a relatively passive passenger unit that rides on a locomotor system.



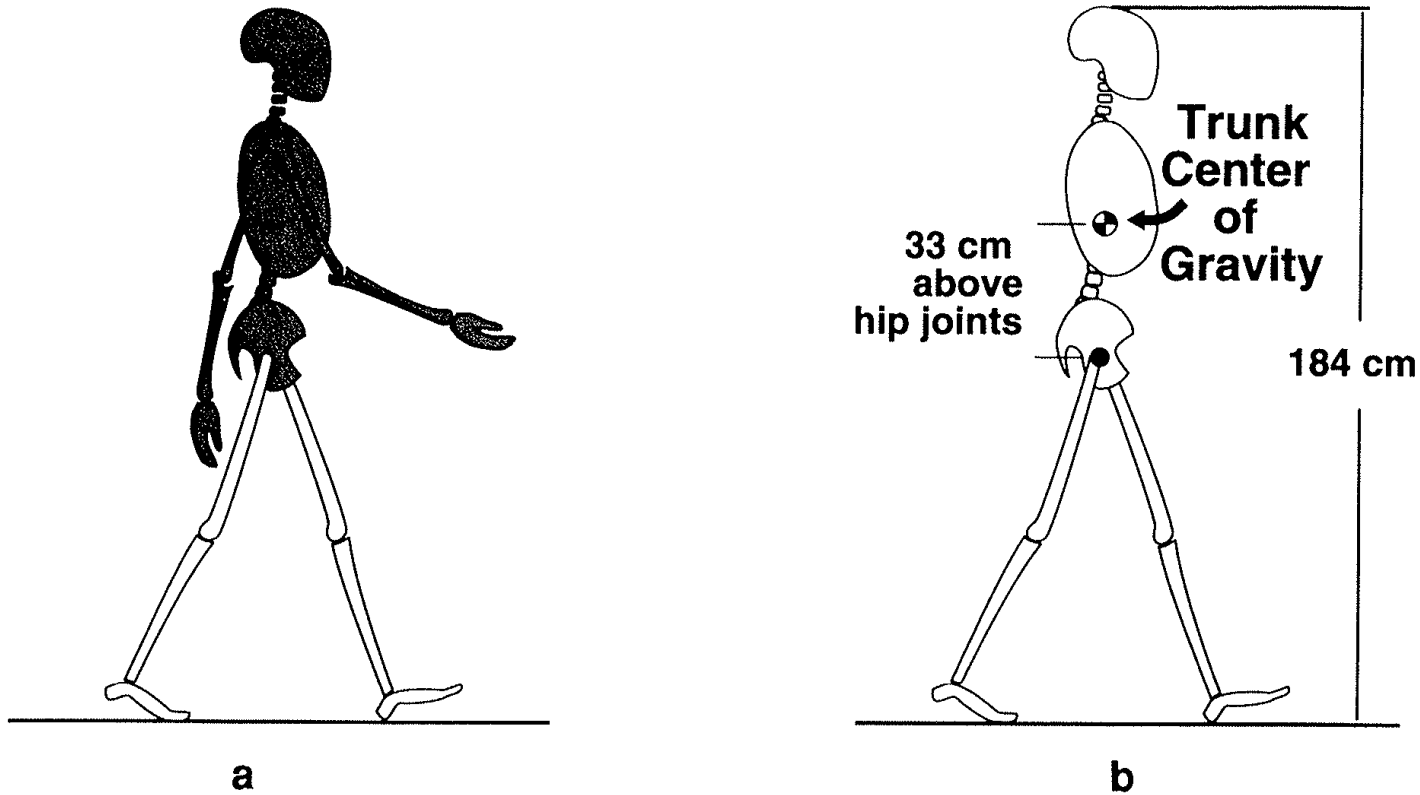
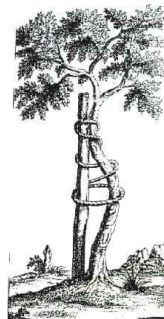
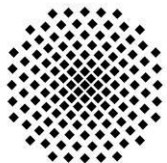
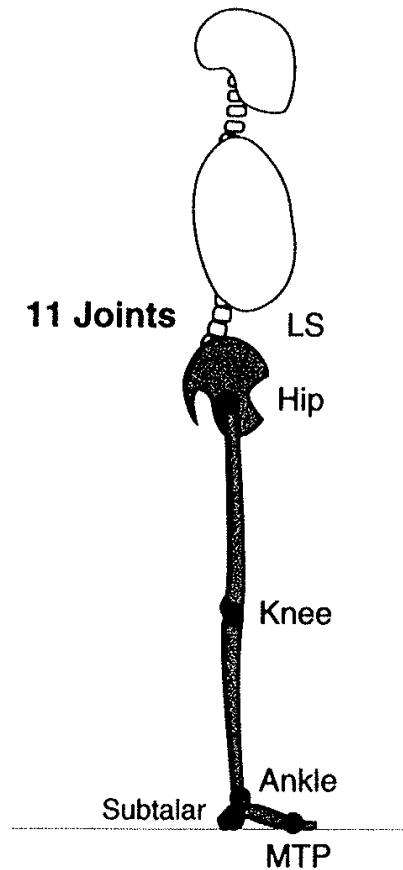


Figure 3.2 The passenger unit. (a) Components are the head, neck, arms, trunk and pelvis. This is called the *HAT* unit. (b) The center of gravity of the HAT lies just anterior to the tenth thoracic vertebra (T_{10}). In a man of average height (184cm) this point is 33cm above the hip joint.

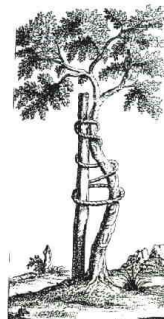
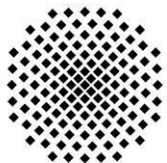
Perry, Gait Analysis, 1992





Perry, Gait Analysis, 1992

Figure 3.3 The locomotor system includes the pelvis and both lower extremities. This means the pelvis is dually considered a part of the passenger unit and the locomotor system. Between the base of the spine and the toes, 11 joints are involved (lumbosacral and both hips, knees, ankles, subtalars, and metatarsophalangeal groups).

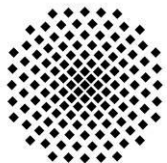


Locomotor Functions

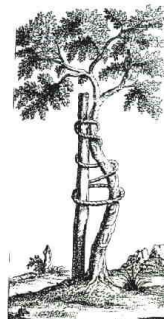
Propulsion
Stance Stability
Shock Absorption
Energy Conservation

Perry, Gait Analysis, 1992

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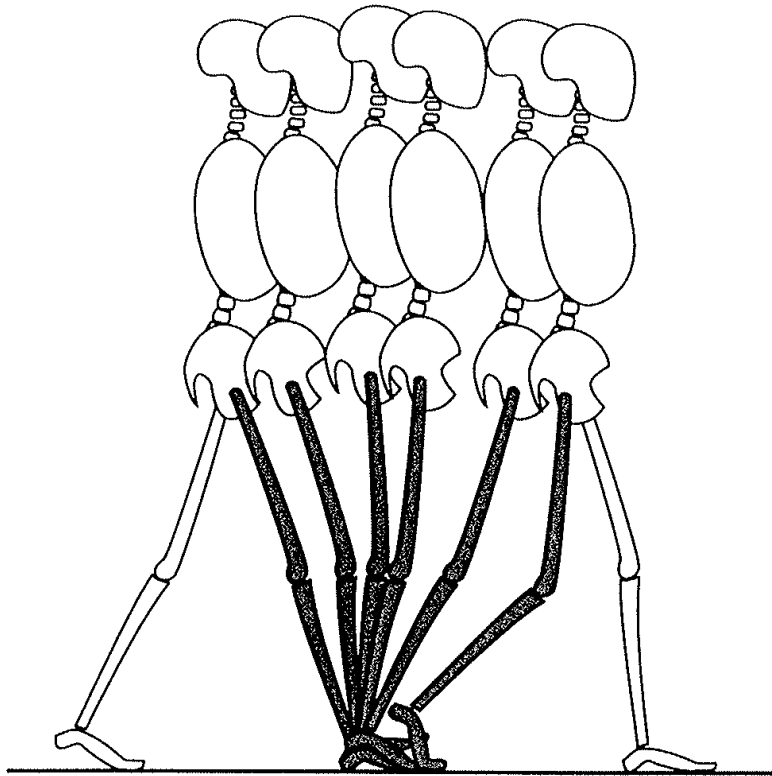


Figure 3.4 During stance, the supporting limb (shaded) provides an advancing base that rolls forward over the foot.

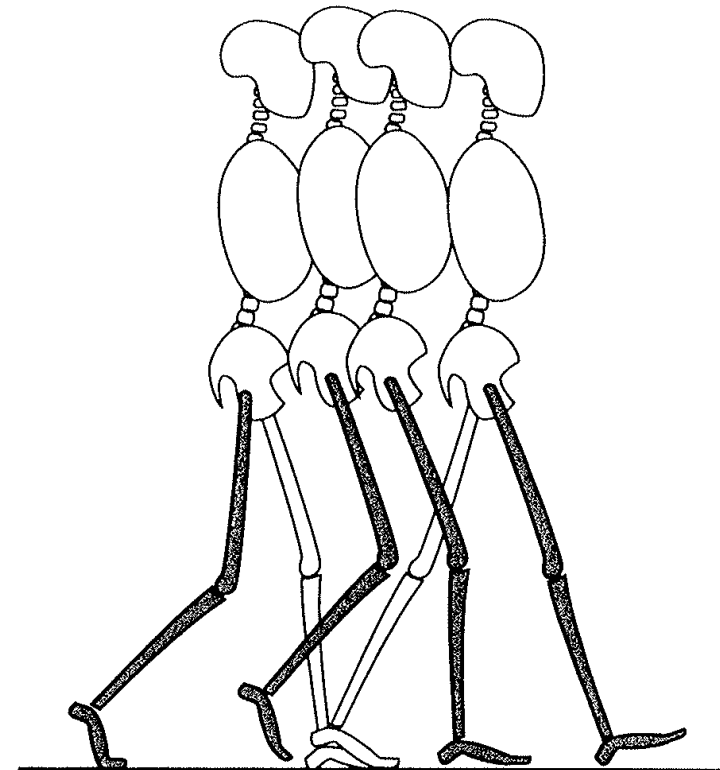
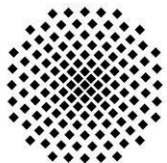


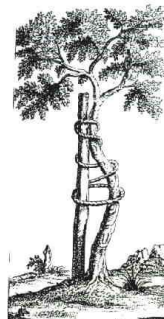
Figure 3.5 During swing, the limb (shaded) advances itself to its next position for weight acceptance.

Perry, Gait Analysis, 1992

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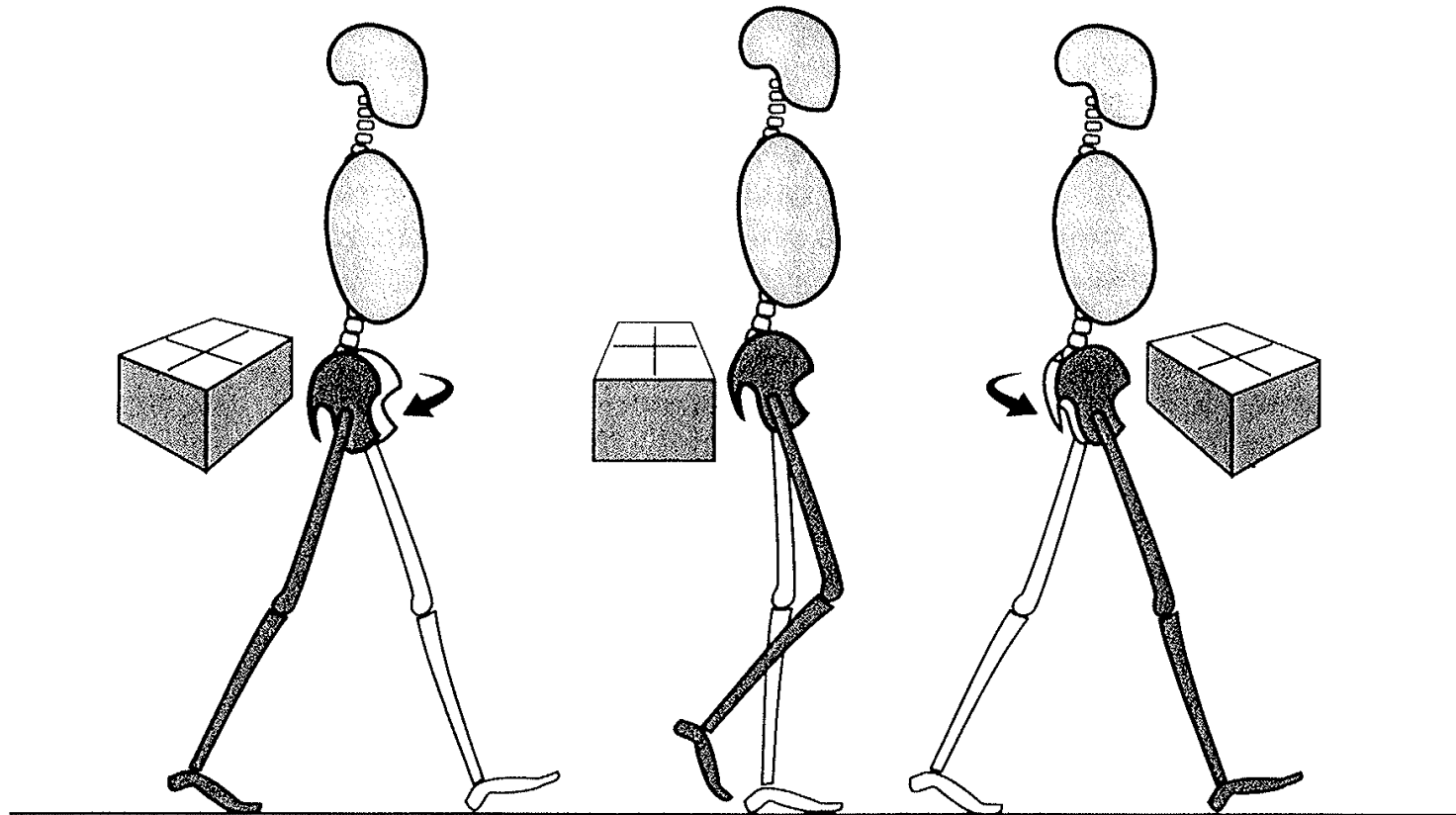
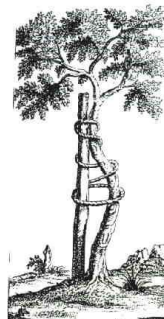
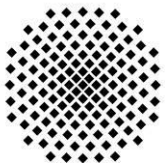
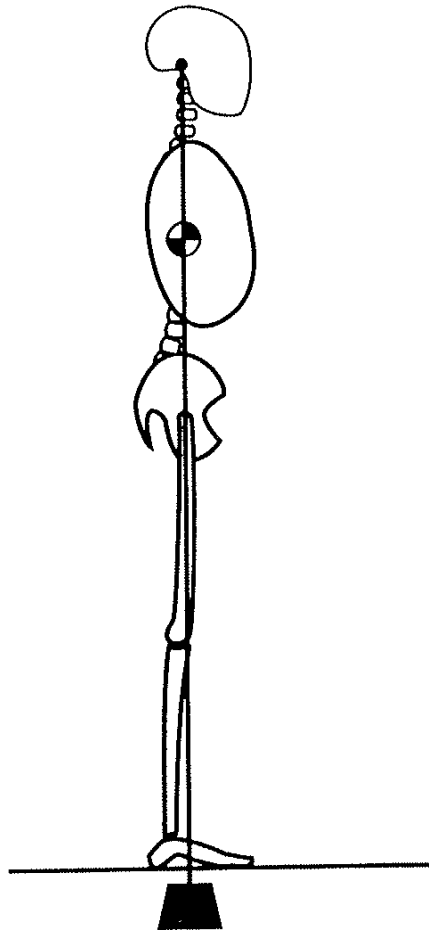


Figure 3.6 Pelvic mobility: Rotation of the pelvis with the swing limb adds to step length. The boxes identify the relation of the pelvis to the reference limb (terminal stance, mid swing, terminal swing).

Perry, Gait Analysis, 1992

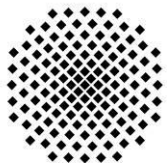




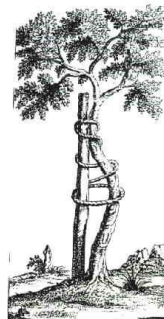
Perry, Gait Analysis, 1992

Figure 3.13 During quiet standing, balanced alignment aligns the body weight vector between the ear canal in the head and anterior to the ankle (near the middle of the supporting foot). It passes slightly anterior to the thoracic spine, just anterior to the knee and barely posterior to the hip joint.

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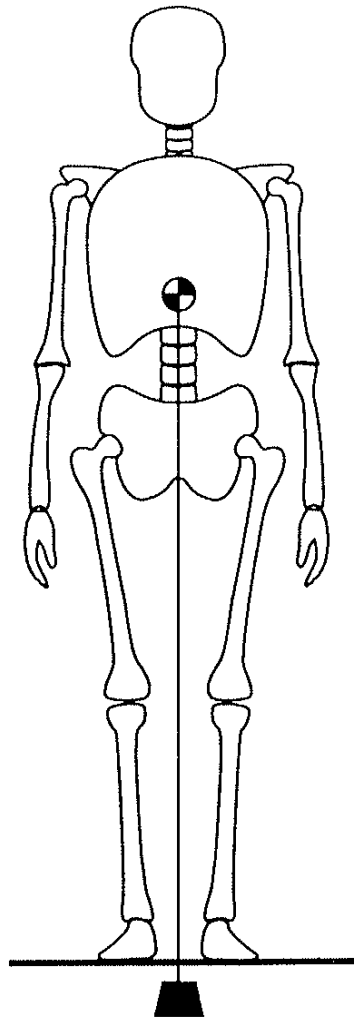
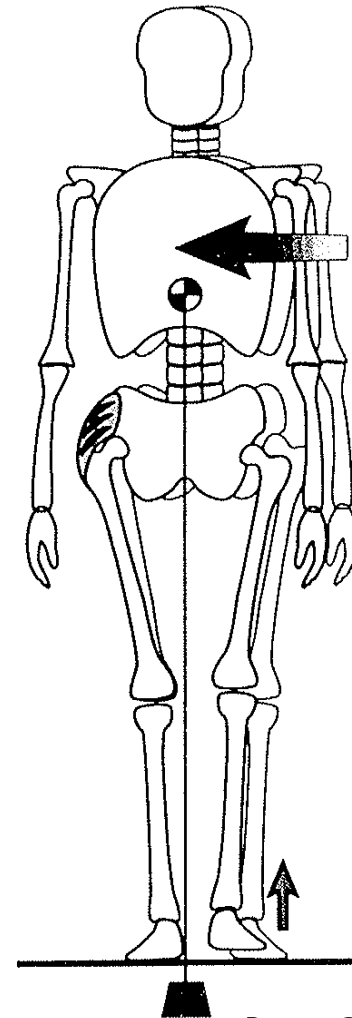


Figure 3.16 In the coronal plane, during quiet standing the body vector (weight line) passes through the middle of the pelvis and between the two feet.

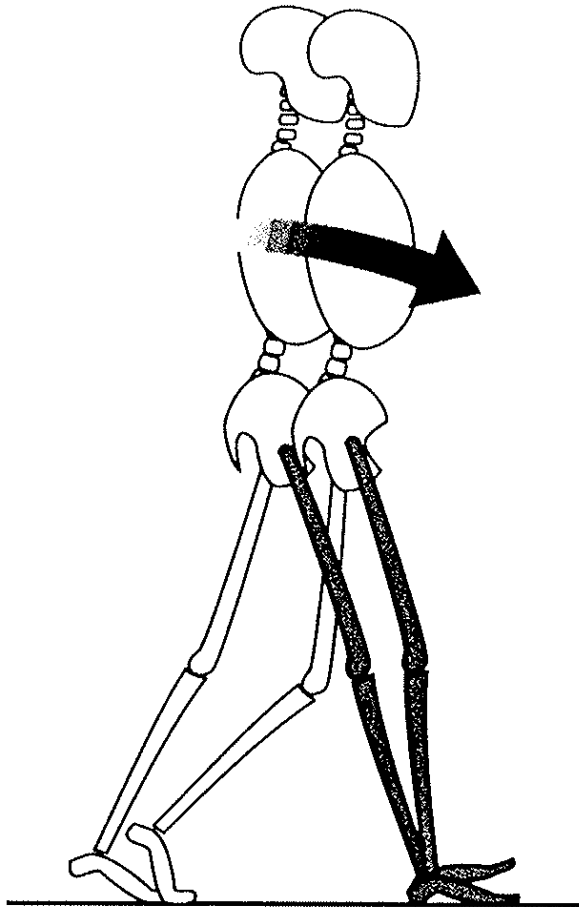


Perry, Gait Analysis, 1992

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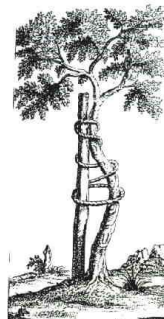
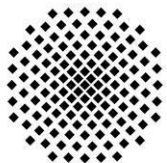
Figure 3.17 Lifting the opposite limb for a step removes the support for that side. Instability is avoided by a shift of the body vector toward the stance limb and strong contraction of the hip abductors to support the unstable pelvis.





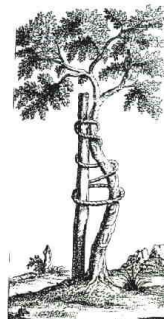
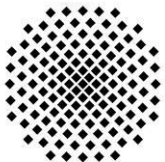
Perry, Gait Analysis, 1992

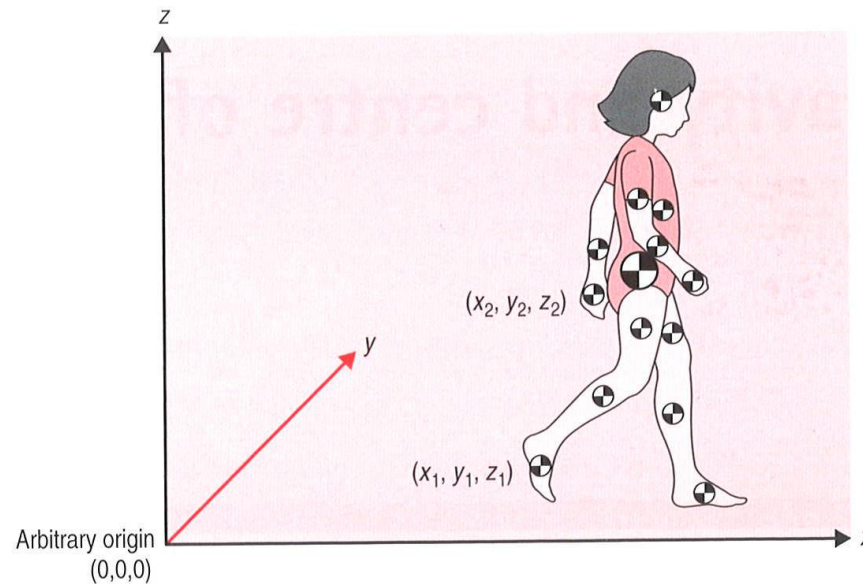
Figure 3.18 For progression, forward fall of body weight (arrow) is the primary force.



Kinematik (gr.: *kinema*, Bewegung)

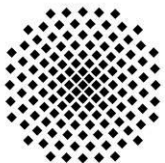
ist die Lehre der Bewegung von Punkten und Körpern im Raum, beschrieben durch die Größen Weg s , Geschwindigkeit v und Beschleunigung a , **ohne die Ursachen** einer Bewegung (Kräfte) zu betrachten.



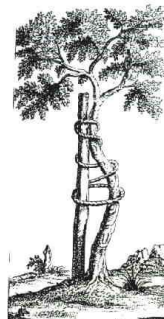


Die Massenschwerpunkte aller Bewegungssegmente können durch einen einzigen Schwerpunkt (total body Center of Mass CoM ersetzt werden: Kirtley 2006

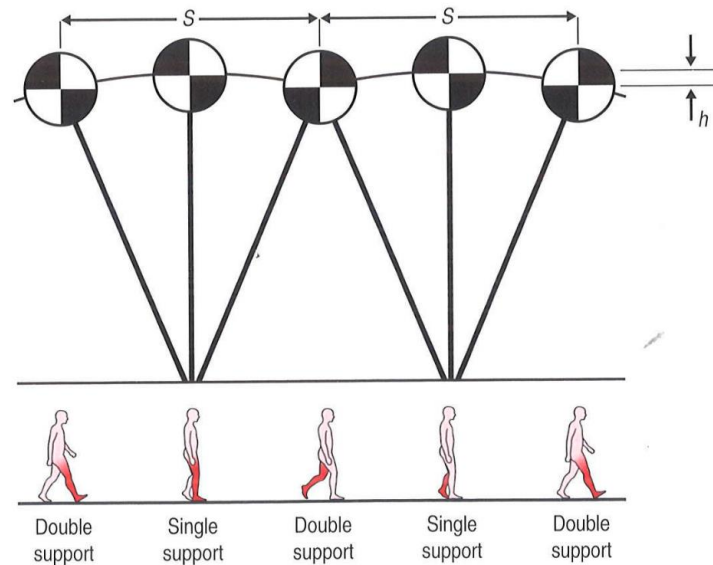
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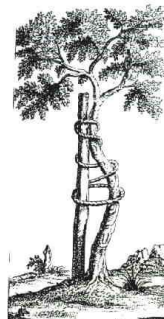
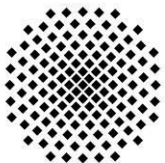
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Invertiertes-Pendel-Modell des Gehens, zeigt hier: CoM steigt in Einbeinunterstützungsphase und sinkt während Zweibeinunterstützung: Kirtley 2006



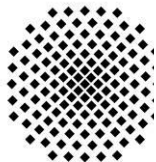
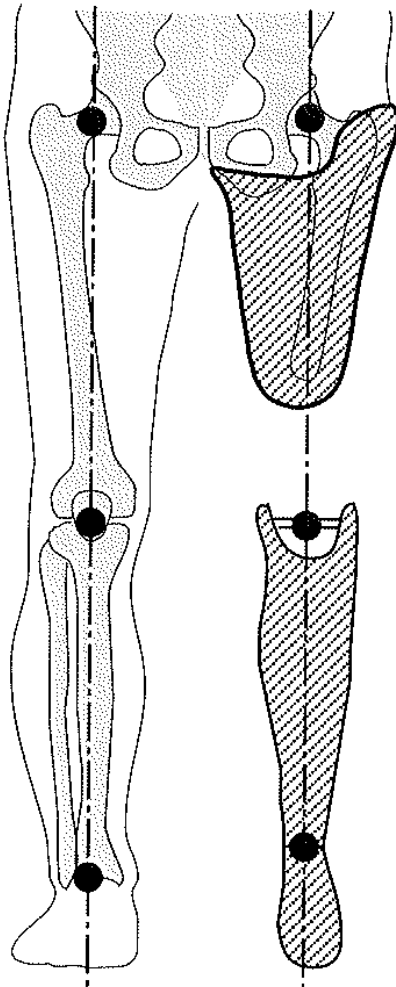


Abb. 5.110 Am Bein sind die Zentren von Hüfte, Knie und oberen Sprunggelenk im Lot (Mikuliczsche Linie). Der Oberschenkelstumpf ist in analoger Weise aufzubauen (Longsche Linie).

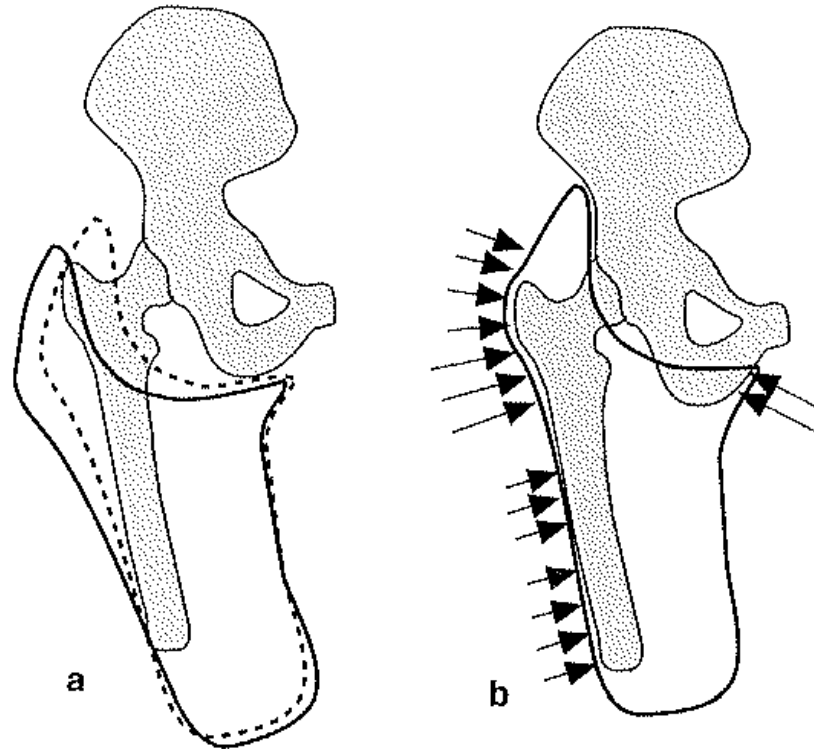


Abb. 5.111 a,b Bei der längsovalen Schaftform verhindert der aufsteigende Sitzbeinast ein Ausweichen des Schaftes zur Seite.

Baumgartner, 1995



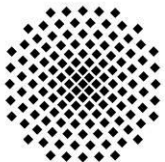
Benefits of the OPRA™ Implant System

- **Elimination of Socket Related Problems¹**
 - Skin irritations, ulcers and perspiration caused by socket – all eliminated
 - Allows volume fluctuation and weight gain/loss
 - Greater comfort during sitting
- **Enhanced Proprioception & Osseoperception²**
 - Intuitive awareness of limb positioning in space
 - Increased sense of feel through the prosthesis
- **Increased Range of Motion and Limb Strength³**
 - Wear time and daily steps increase
 - Improved force production in residuum
- **Ease of Prosthetic Attachment and Detachment⁴**

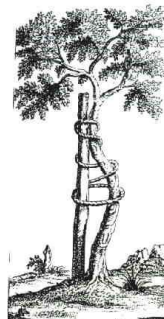
SCIENTIFIC DATA & RESOURCES



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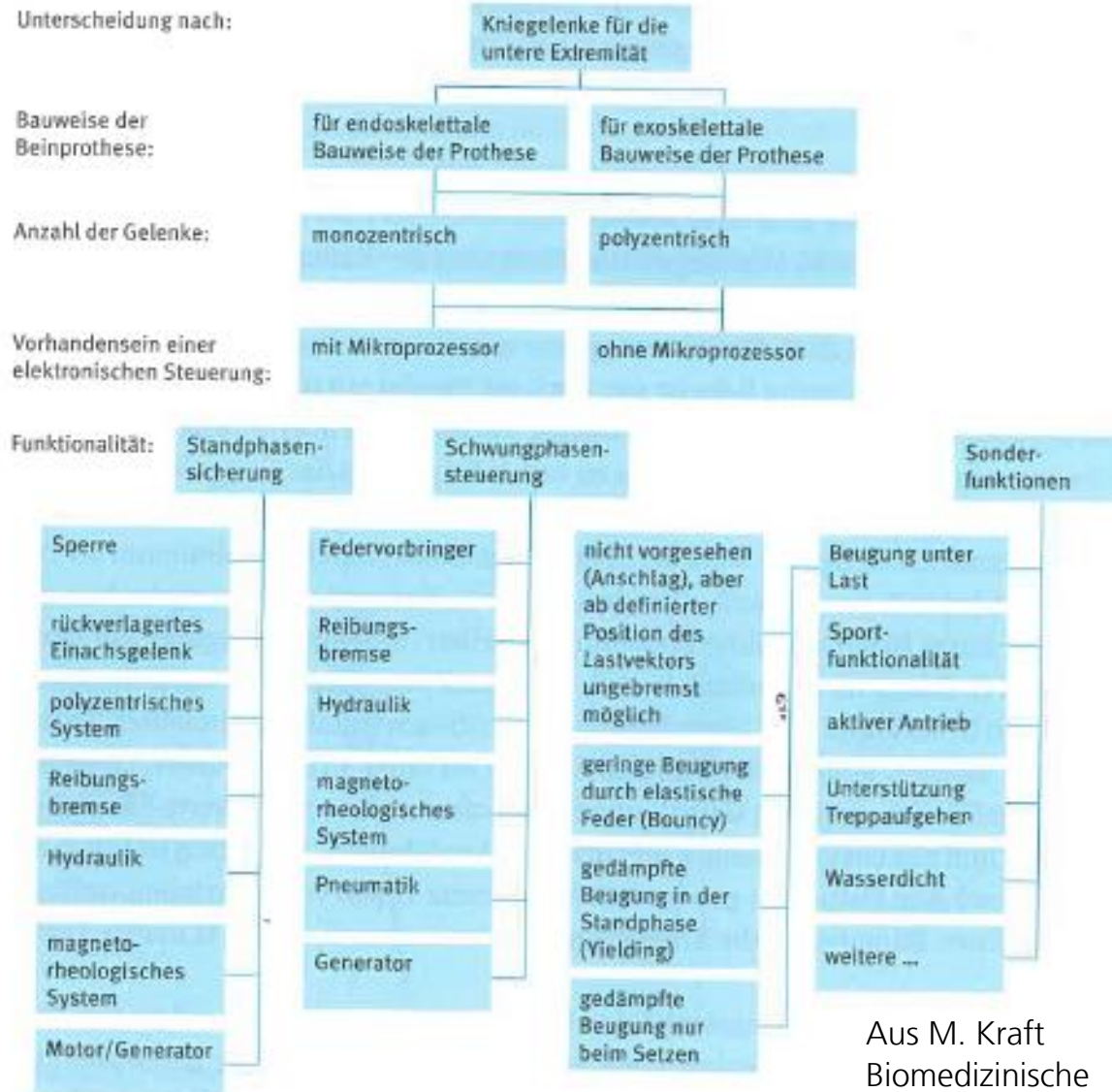
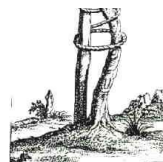


Abb. 3.22: Unterscheidungsmerkmale prothetischer Kniegelenke.

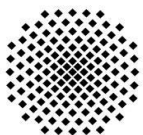
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Technik, De
Gruyter 2015



Warum Evidenz-basierte Medizin?

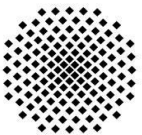
Strength	Level	Design	Randomization	Control
High	Level 1	Randomized control trial (RCT)	Yes	Yes
		Meta-analysis of RCT with homogeneous results	No	
	Level 2	Prospective comparative study (therapeutic)	No	Yes
		Meta-analysis of Level 2 studies or Level 1 studies with inconsistent results	No	
	Level 3	Retrospective Cohort Study	No	Yes
		Case-control Study	No	Yes
		Meta-analysis of Level 3 studies	No	
	Level 4	Case Series	No	No
Low	Level 5	Case Report	No	No
		Expert Opinion	No	No
		Personal Observation	No	No

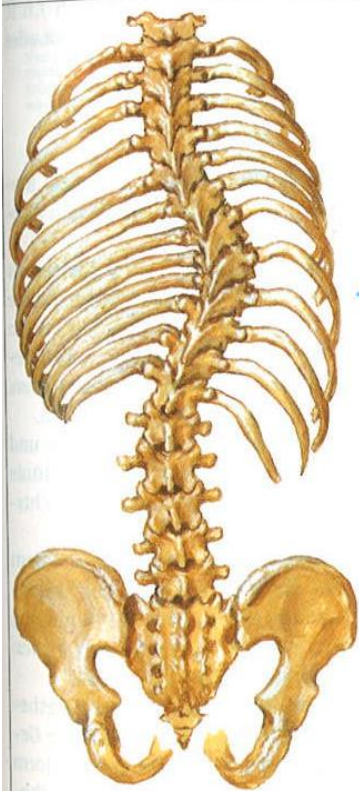
Source: hydrassoc.org



Die Gelenkfehlstellung = Deformität

Beispiel Skoliose

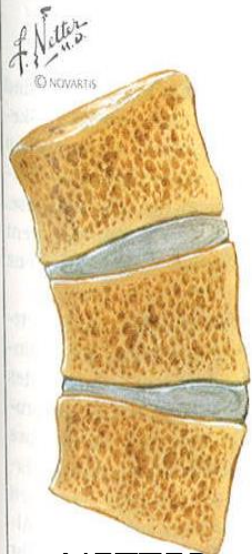




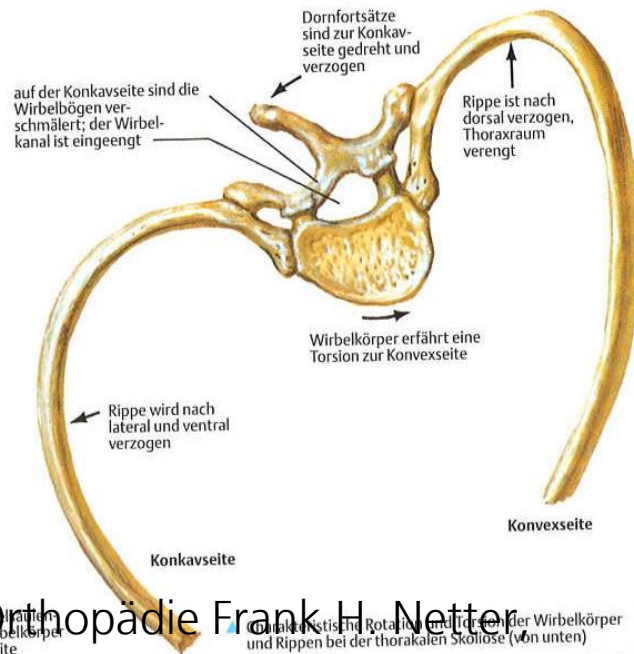
Die Rippen stehen auf der Konkavseite der Krümmung eng beisammen, auf der Konvexseite weit auseinander. Die Wirbelkörper sind mit den Dornfortsätzen und Bogenwurzeln zur Konkavseite gedreht



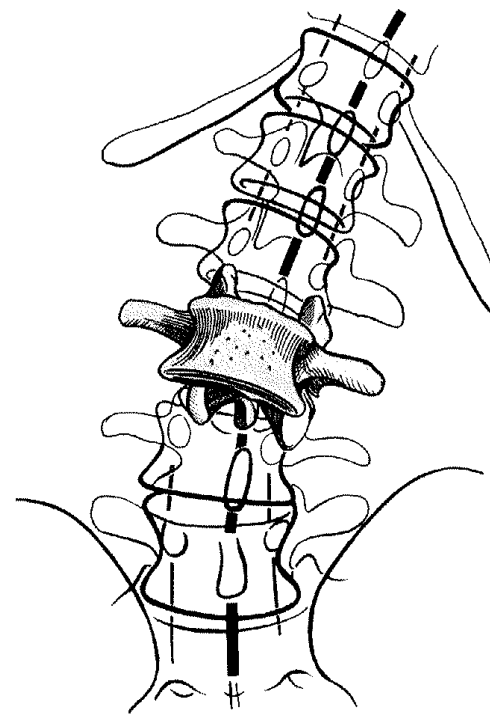
Für die thorakale Skoliose typischer dorsaler Rippenbuckel auf der Konvexseite



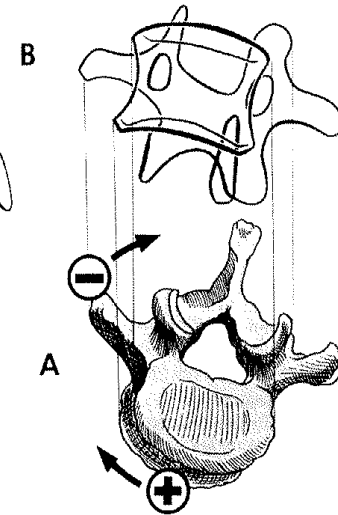
Schnitt durch ein korrigiertes Wirbelsäulen-segment. Höhenminderung der Wirbelkörper und Bandscheiben auf der Konkavseite



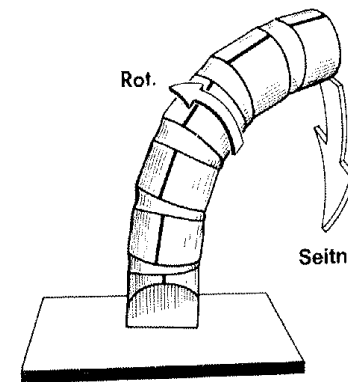
Kombinierte Rotations- und Torsionsbewegung der Wirbelkörper und Rippen bei der thorakalen Skoliose (von unten)



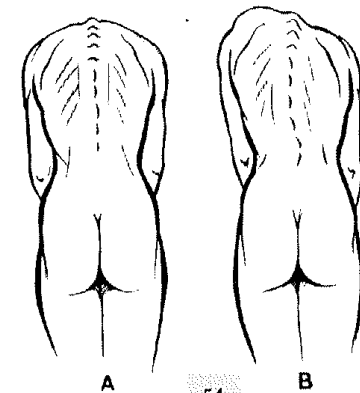
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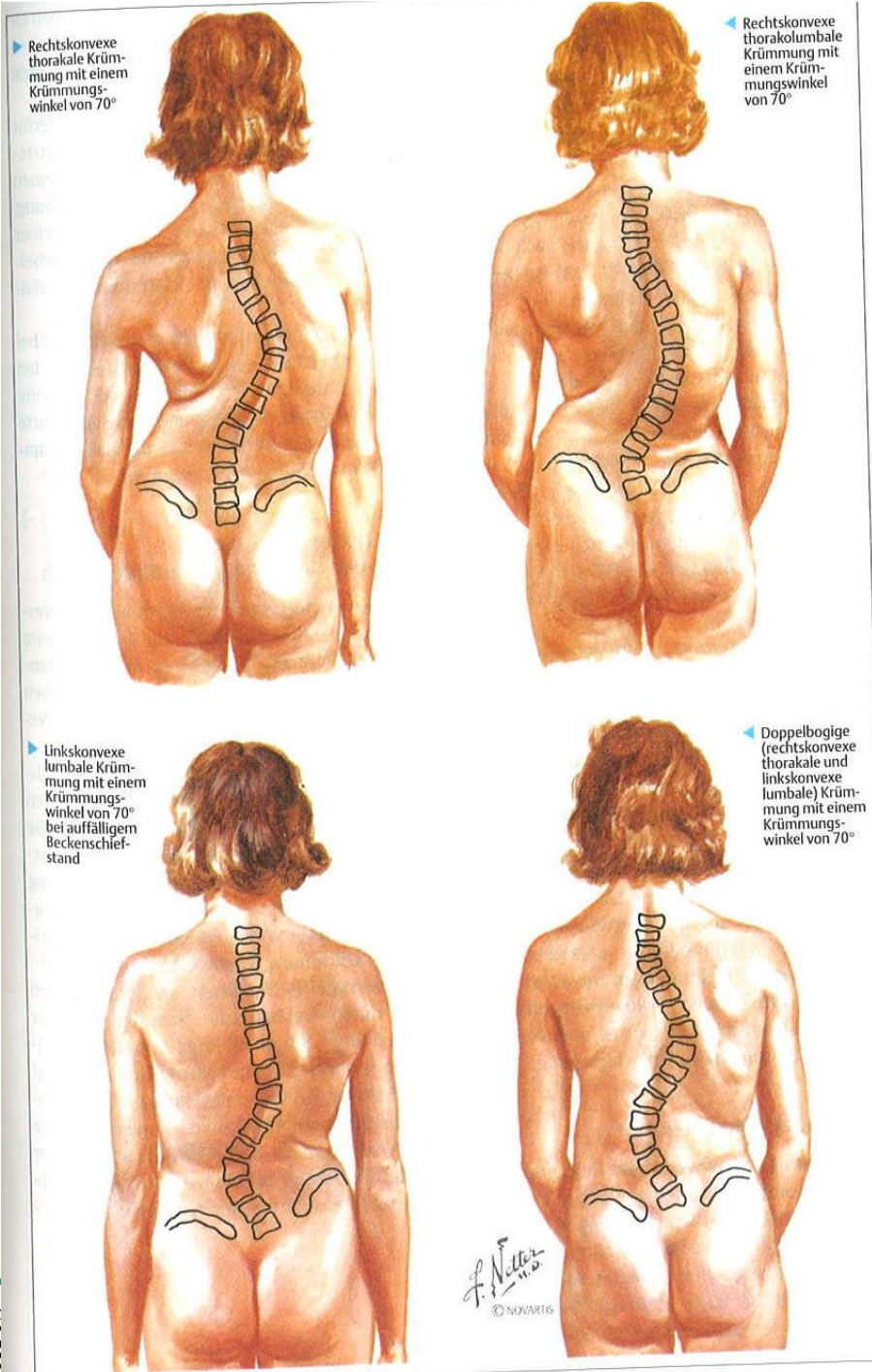


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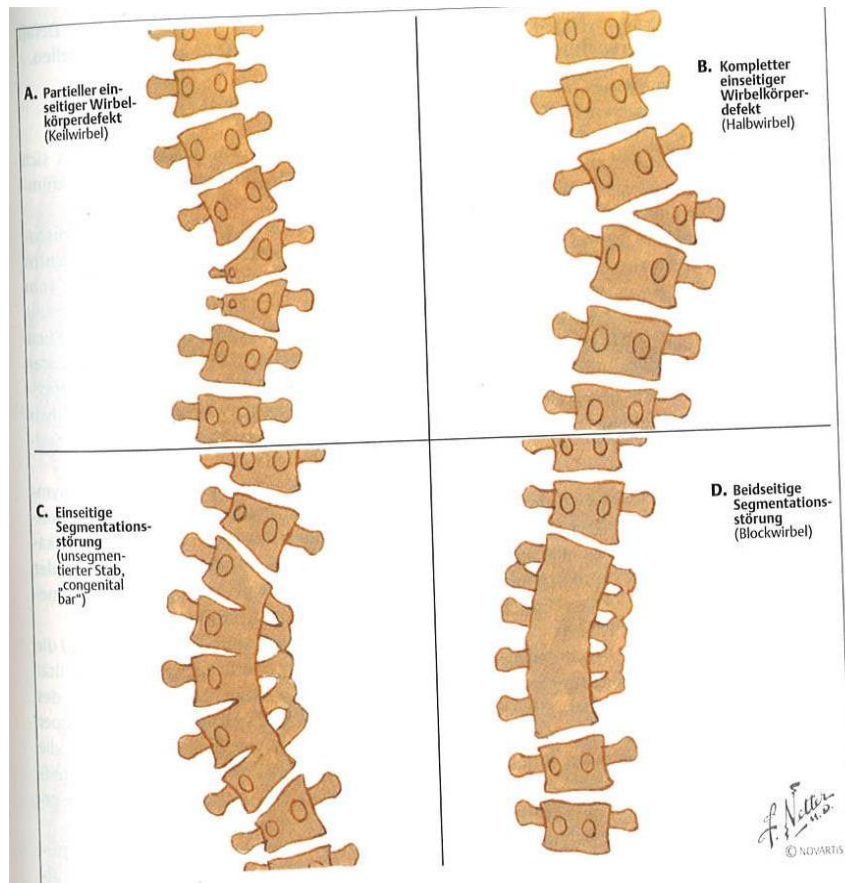


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Kapandji, Anatomie der Gelenke, 1995

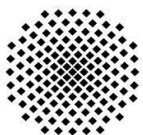
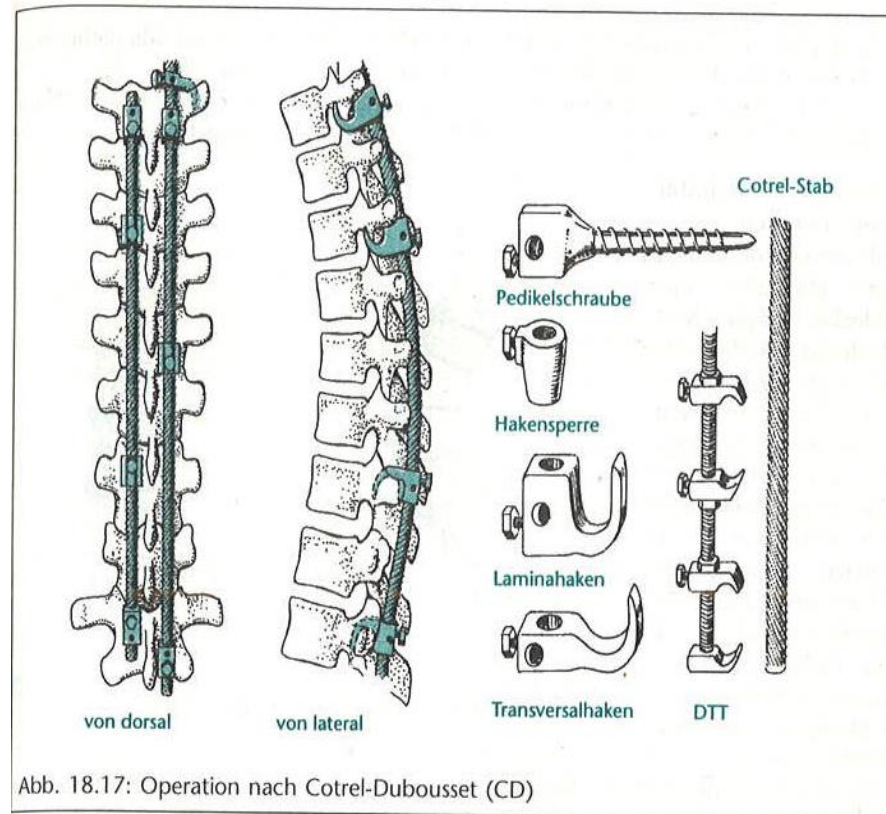
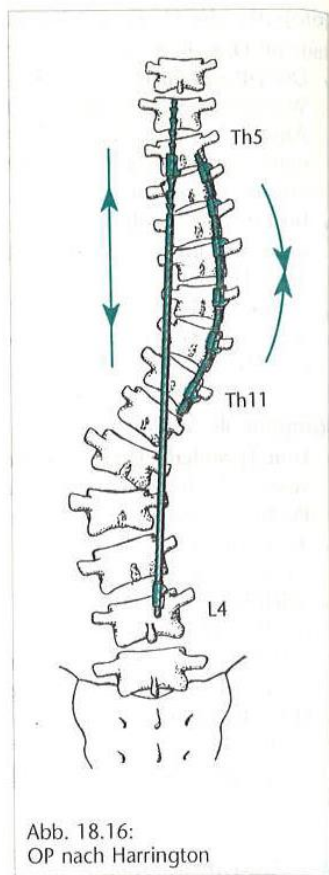


NETTERs Orthopädie Frank H. Netter,
2000



NETTERs Orthopädie Frank H. Netter,
2000





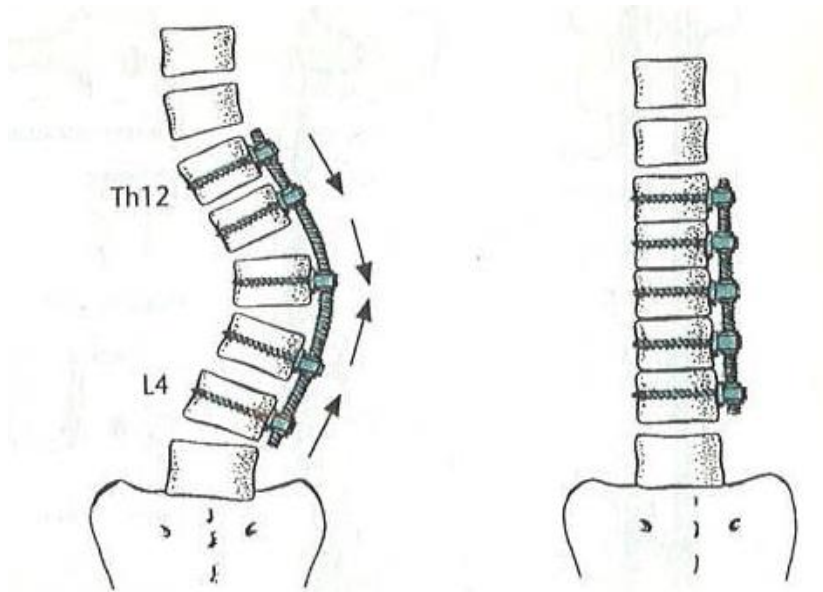
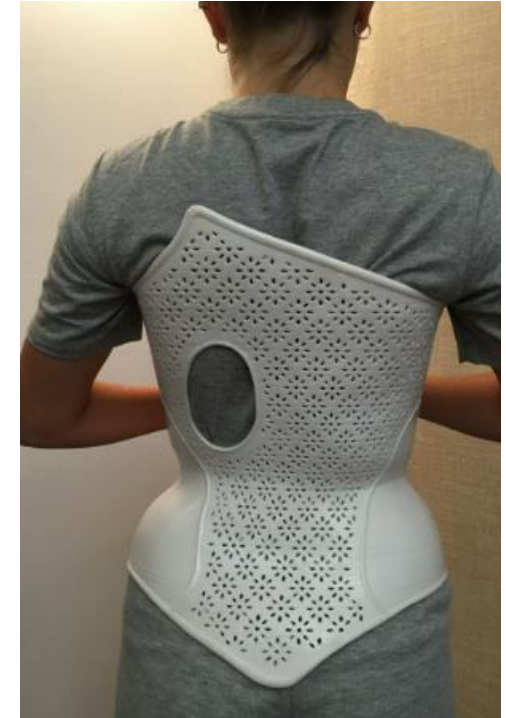


Abb. 18.18:
Ventrale Derotationsspondylodese nach Zielke



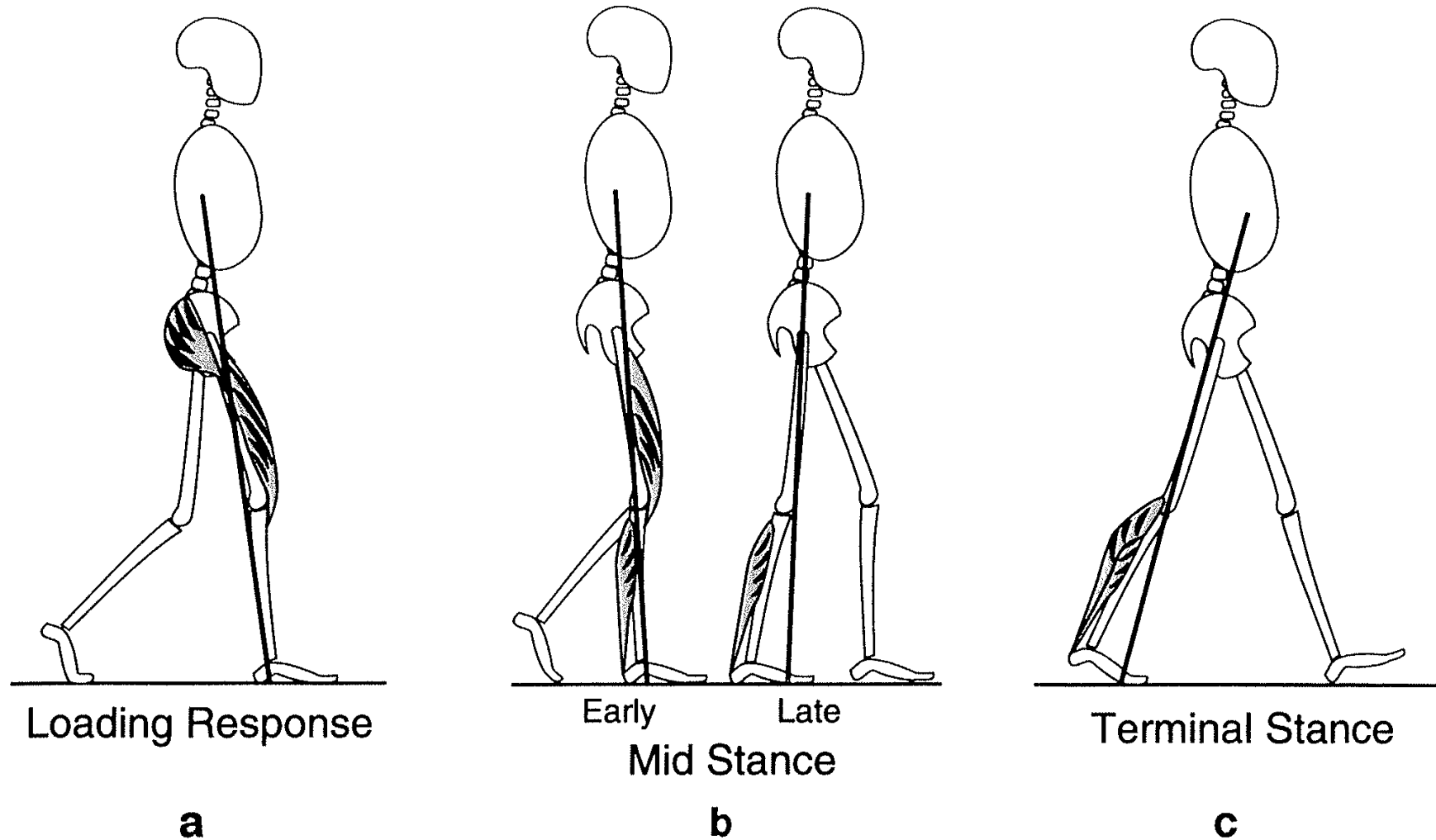
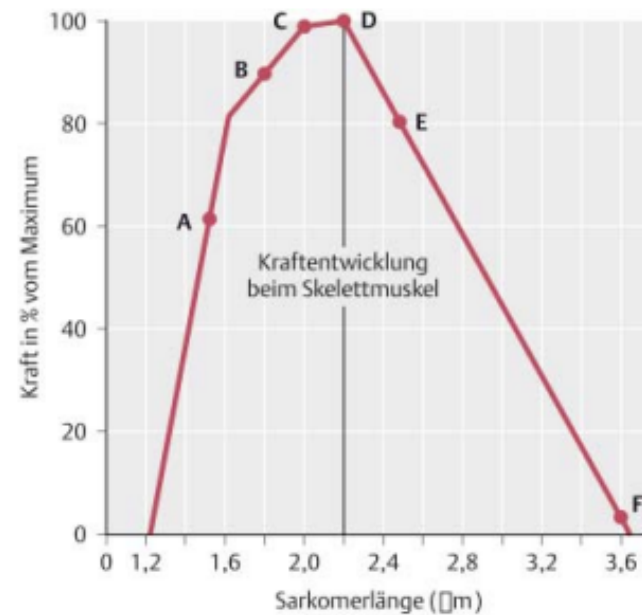
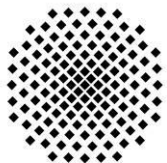


Figure 3.15 During walking, dynamic stability is modified by continual realignment of the vector to the joints. Loading Response: the vector is anterior to the hip and posterior to the knee and ankle. Mid Stance: At the onset of this phase (early) the body weight vector is slightly behind the knee but anterior to the ankle. By the end of the phase (late) the vector has moved forward of the ankle and the knee. At the hip the vector has moved posteriorly. Terminal Stance: The vector is posterior to the hip, anterior to the knee and maximally forward of the ankle.

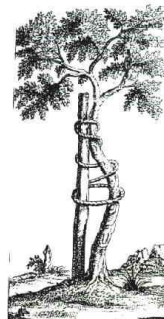
aus: Huppelsberg, Physiologie (ISBN 9783131364333), © 2009 Georg Thieme Verlag KG



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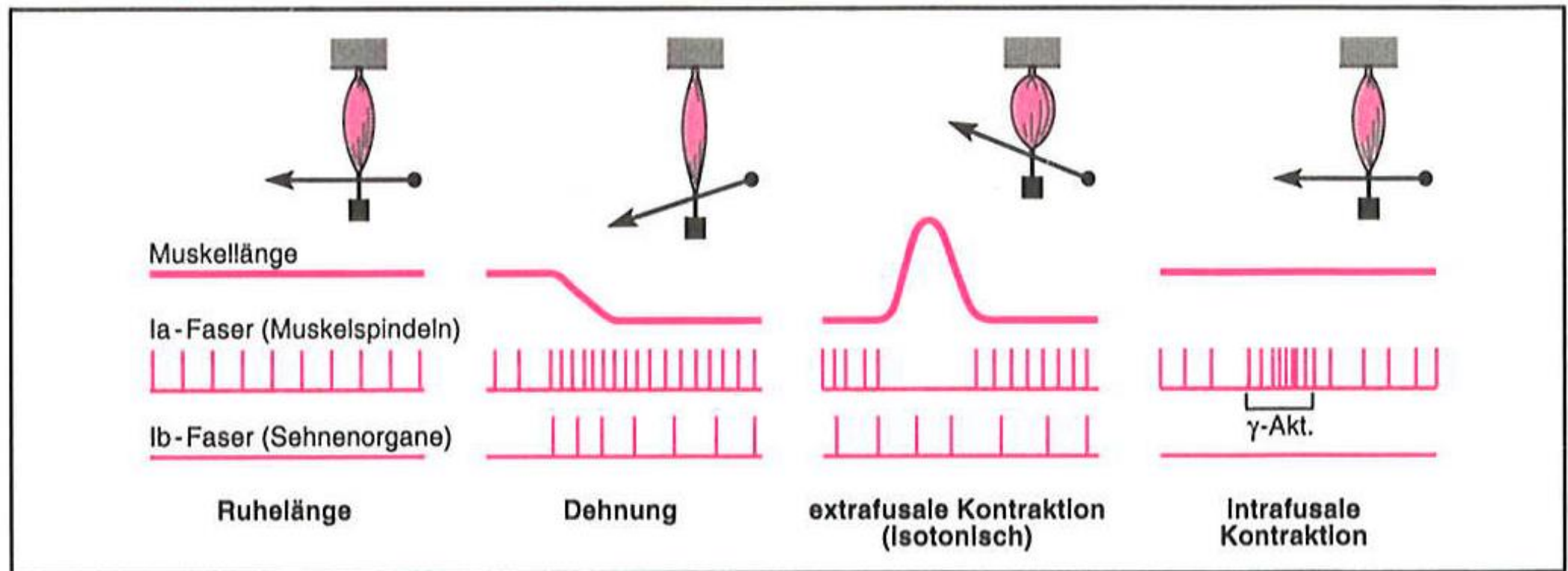


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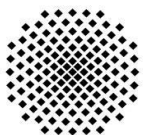


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Entladungsmuster der Muskelspindeln und Sehnenorgane



RF Schmidt: Memorix Physiologie, 1992



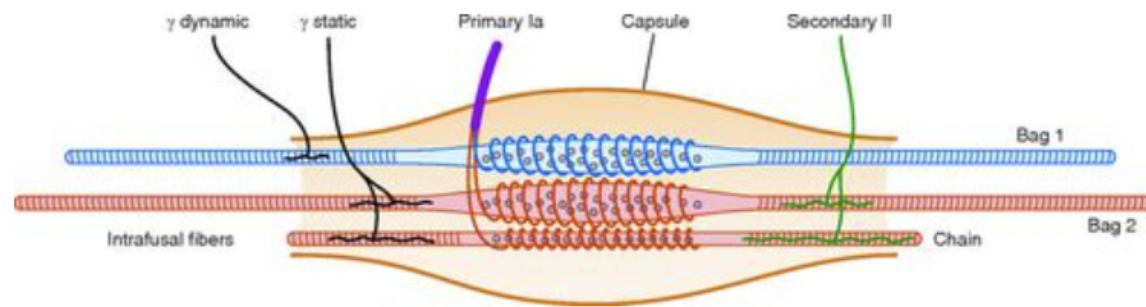


Figure 1.

Diagrammatic representation of the mammalian muscle spindle. The intrafusal fibers include the large nuclear bag 1 and bag 2 fibers together with the smaller nuclear chain fibers. Ends of the bag fibers extend beyond the capsule while chain fibers lie within the limits of the capsule. Large, group Ia afferent fibers terminate as primary endings, making spiral terminations around the nucleated portions of all three intrafusal fiber types. Smaller, group II afferent fibers terminate as secondary endings, lying to one side of the primary endings and supplying bag 2 and chain fibers. Gamma dynamic (γ dynamic) fusimotor fibers innervate bag 1 fibers, while gamma static (γ static) fusimotor fibers innervate bag 2 and chain fibers. [Redrawn from Proske (301).]

THE PROPRIOCEPTIVE SENSES: THEIR ROLES IN SIGNALING BODY SHAPE, BODY POSITION AND MOVEMENT, AND MUSCLE FORCE, *Physiol Rev* 92: 1651–1697, 2012 doi:10.1152/physrev.00048.2011 16510031-9333/12 Copyright © 2012 the American Physiological Society



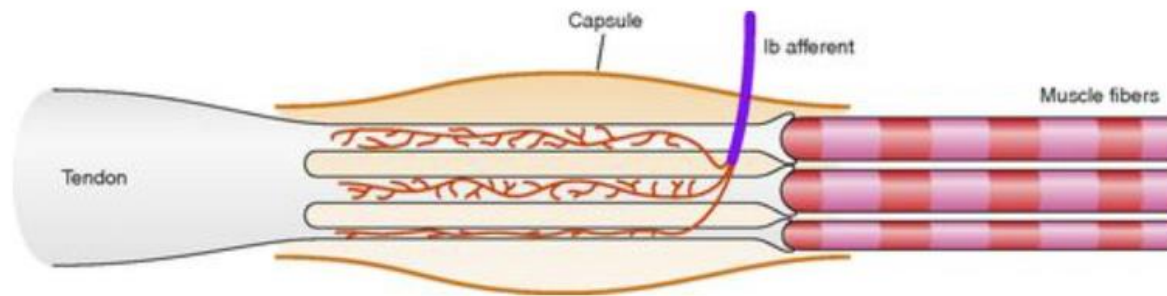
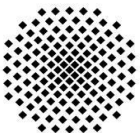


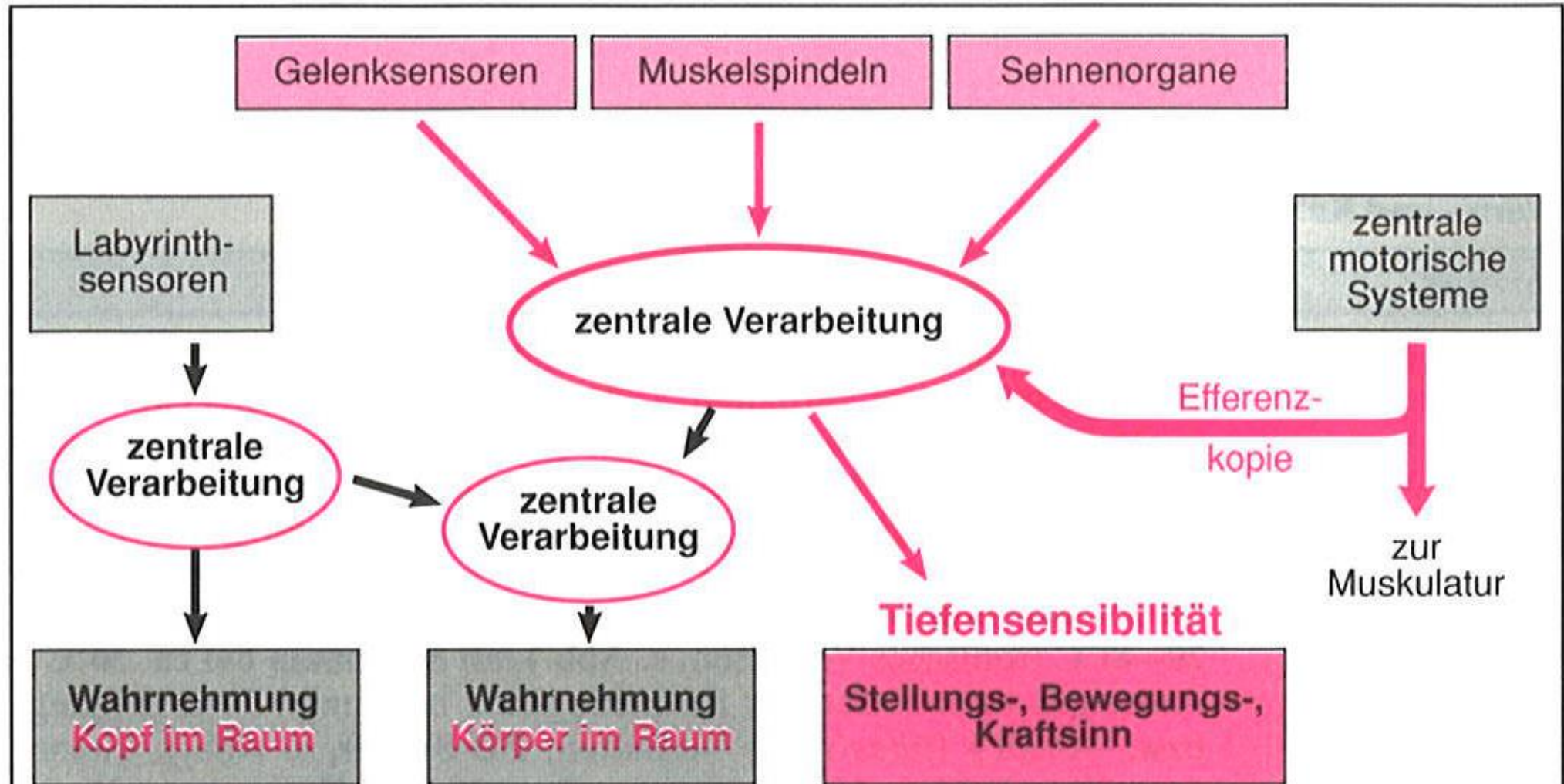
Figure 2.

Diagrammatic representation of the mammalian Golgi tendon organ. The Group Ib axon penetrates the receptor capsule and branches, each branch terminating on a tendon strand that is attached to a muscle fiber. A typical tendon organ has 10 or more muscle fibers attached to it, each fiber belonging to a different motor unit. Contraction of a motor unit supplying a tendon organ stretches the tendon strand to which its muscle fiber is attached, generating activity in the Ib axon. [Redrawn in part from Proske (302).]

THE PROPRIOCEPTIVE SENSES: THEIR ROLES IN SIGNALING BODY SHAPE, BODY POSITION AND MOVEMENT, AND MUSCLE FORCE, *Physiol Rev* 92: 1651–1697, 2012 doi:10.1152/physrev.00048.2011 16510031-9333/12 Copyright © 2012 the American Physiological Society

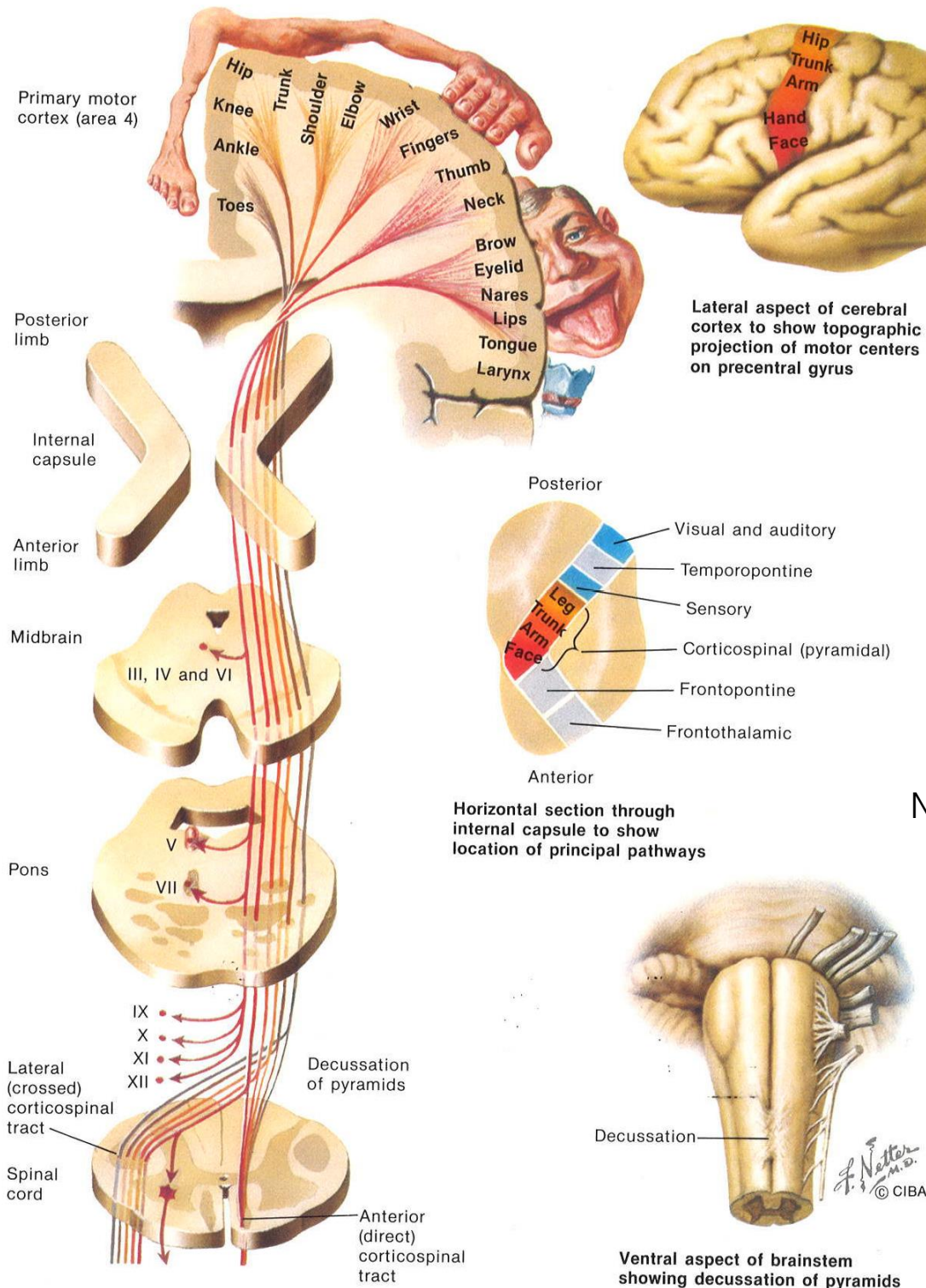


Für die **Wahrnehmung der Tiefensensibilität** ist eine integrative Verarbeitung der affe-
renten Zuflüsse notwendig [Nach Birbaumer N, Schmidt RF (1991) a. o. a.O.]

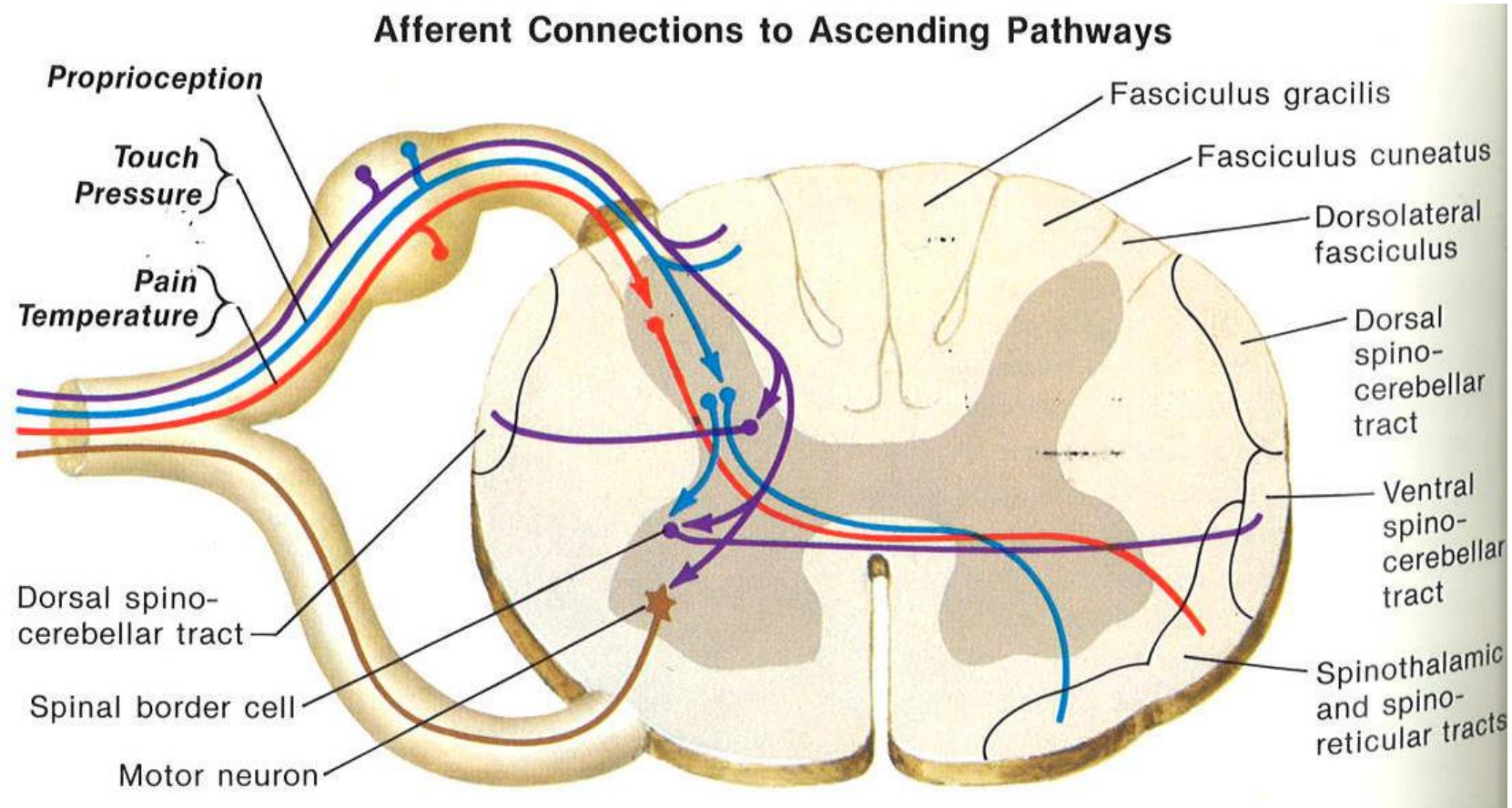


Keiner der obigen Sensoren kann für sich allein *Tiefensensibilität* vermitteln. Die dafür notwendige **zentrale Verarbeitung** (s. Abb.) schließt auch **Efferenzkopien** ein, um zwangsläufige *Mehrdeutigkeit afferenter Information* (z.B. Aktivierung primärer Muskelspindelafferenzen entweder *durch Dehnung* oder *intrafusale Kontraktion*) zu beseitigen. Zusammenarbeit auch mit dem Gleichgewichtsorgan, um Stellung von Kopf und Körper im Raum wahrzunehmen

Pyramidal System

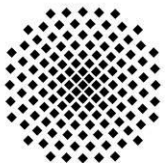


Netter: Neurophysiologie, 1992

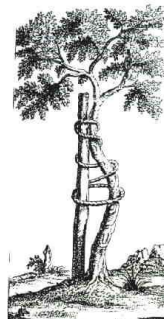


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Netter: Neurophysiologie, 1992

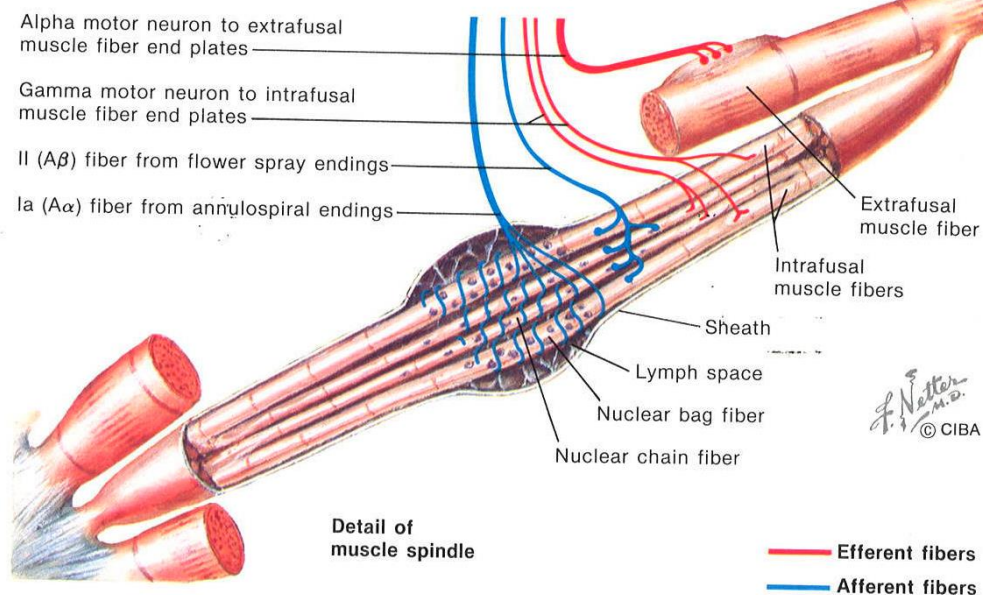
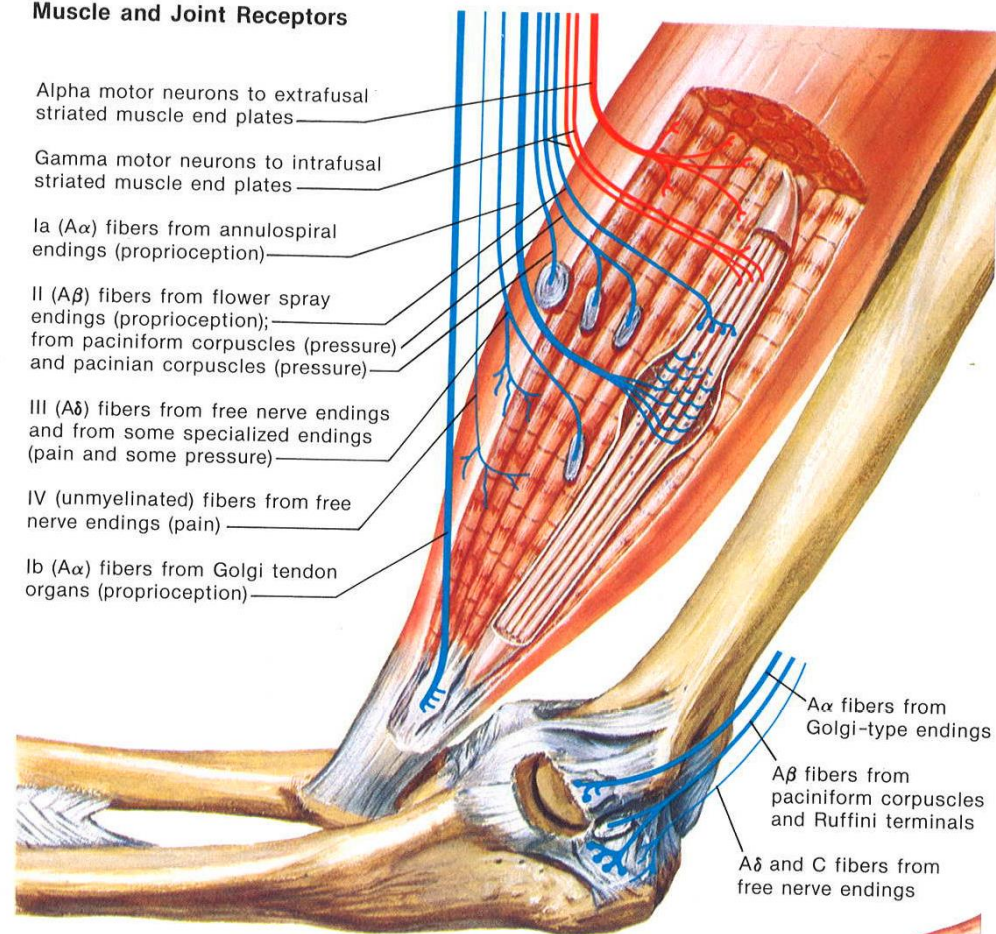


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Muscle and Joint Receptors

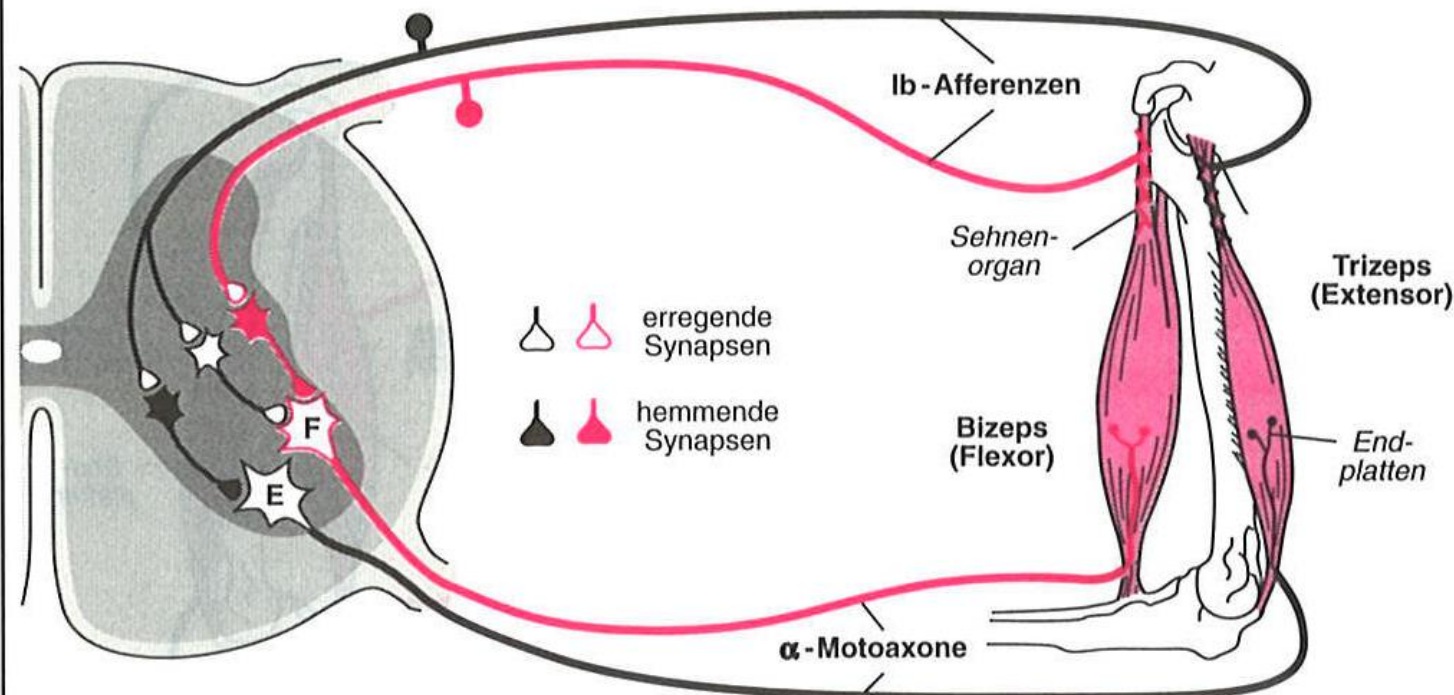


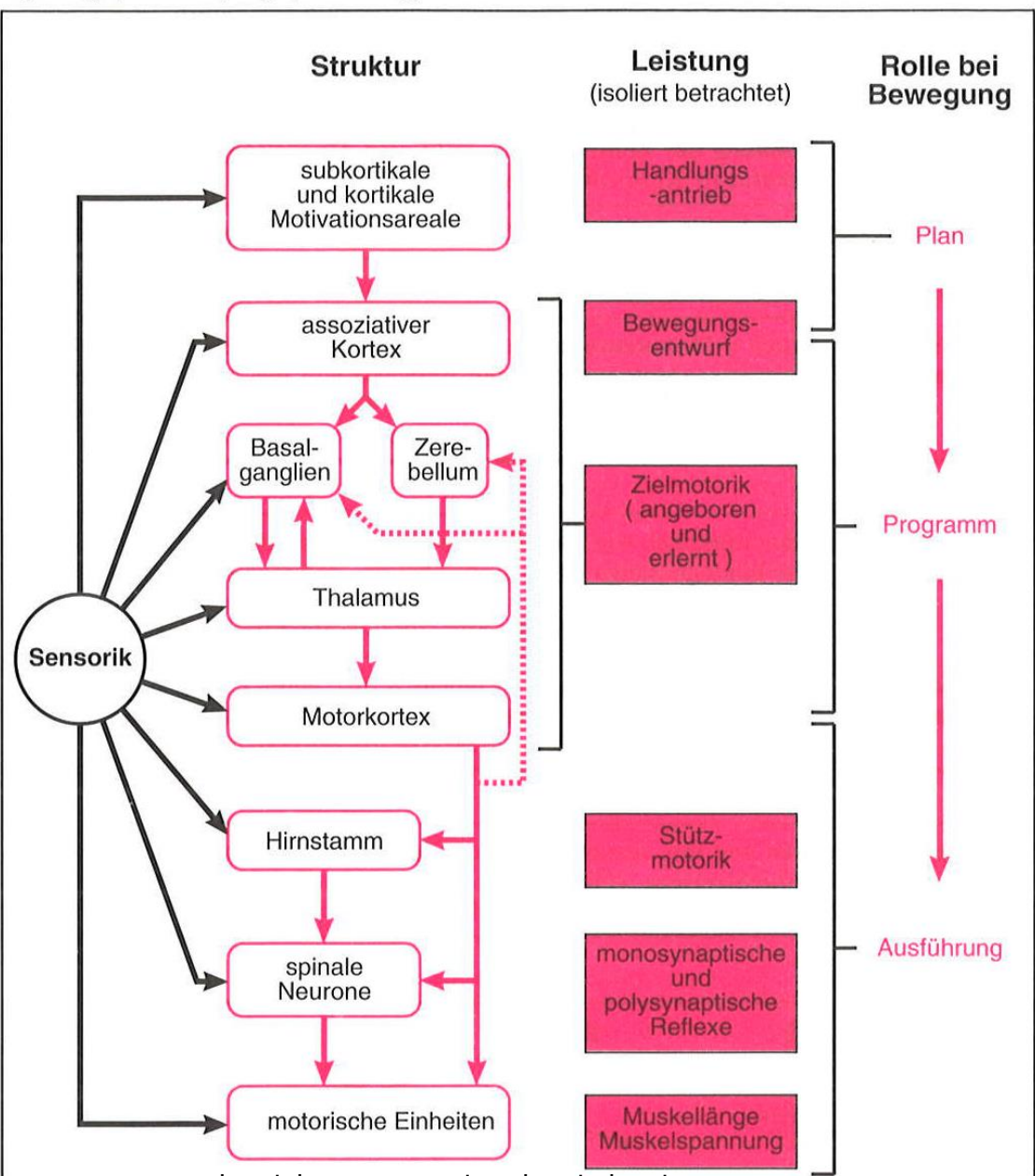
Netter: Neurophysiologie, 1992

Die Sehnenorgane wirken spiegelbildlich zu den primären Muskelspindelafferenzen: **autogene Hemmung und **antagonistische Erregung****

Anteil	Definition / Beschreibung / Kommentar
1 u. 2	Sehnenorgane und Ib-Fasern des <i>homonymen</i> Muskels. Aktivierung der Reflexbögen durch Spannungszunahme (<i>Dehnung</i> oder <i>isometrische Kontraktion</i>)
3	Homonym u. agonistisch: 1–2 Interneurone, die <i>hemmend</i> auf Motoneuron wirken. Antagonistisch: Interneuron mit <i>erregender</i> Synapse auf Motoneuron (<i>di-</i> und <i>trisynaptische</i> Reflexbögen)
4 u. 5	<i>Homonyme</i> und <i>agonistische</i> motorische Einheiten werden gehemmt: auto-gene Hemmung . Nimmt Muskelspannung ab, nimmt auch autogene Hemmung ab: Disinhibition . <i>Antagonistische</i> motorische Einheiten: Erregung (Zunahme des Muskeltonus). Hauptfunktion beider Reflexbögen: Spannungskonstanthaltung

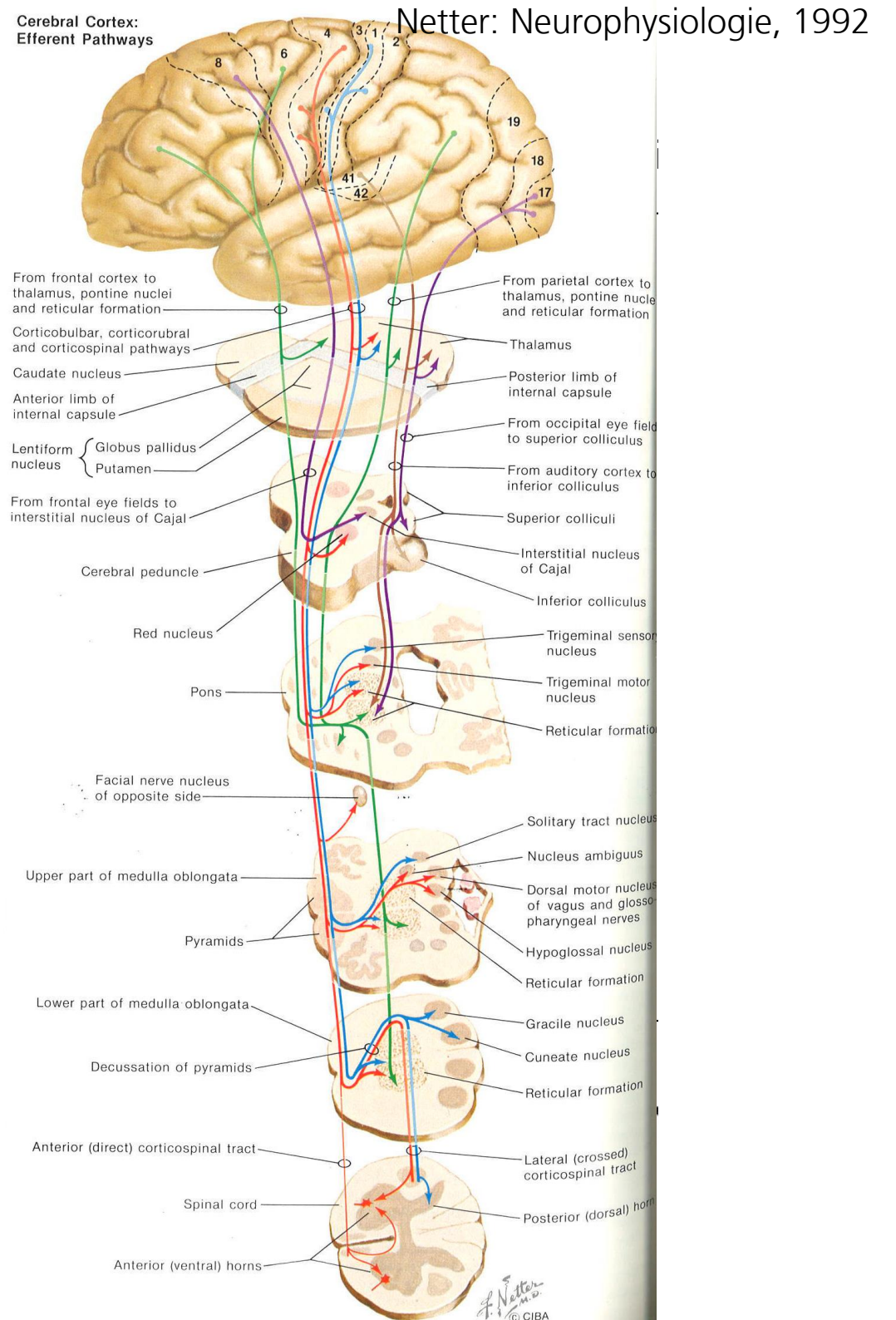
RF Schmidt: Memorix Physiologie, 1992

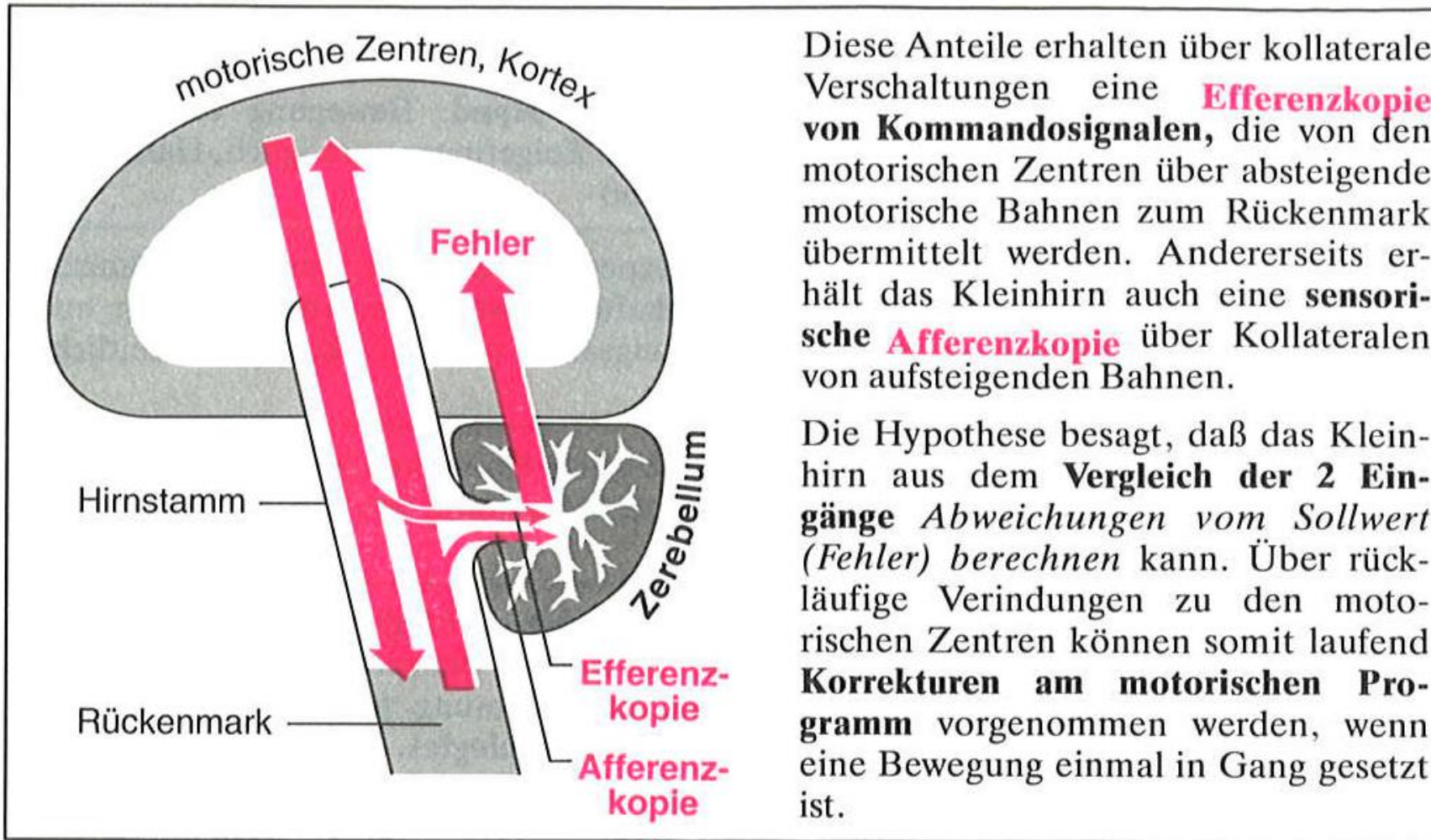




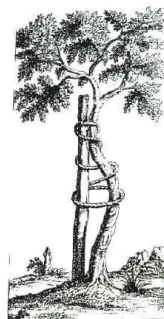
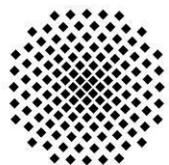
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Die wichtigsten Strukturen und ihre Verbindungen sind in der linken Säule angeordnet. Der Einfachheit halber wurden alle sensorischen Zuflüsse ganz links zusammengefaßt. Die mittlere Säule betont die bei isolierter Betrachtungsweise herausragenden Leistungen der einzelnen Abschnitte, die rechte gibt die Rolle bei der Initiierung und Durchführung einer Bewegung wieder.

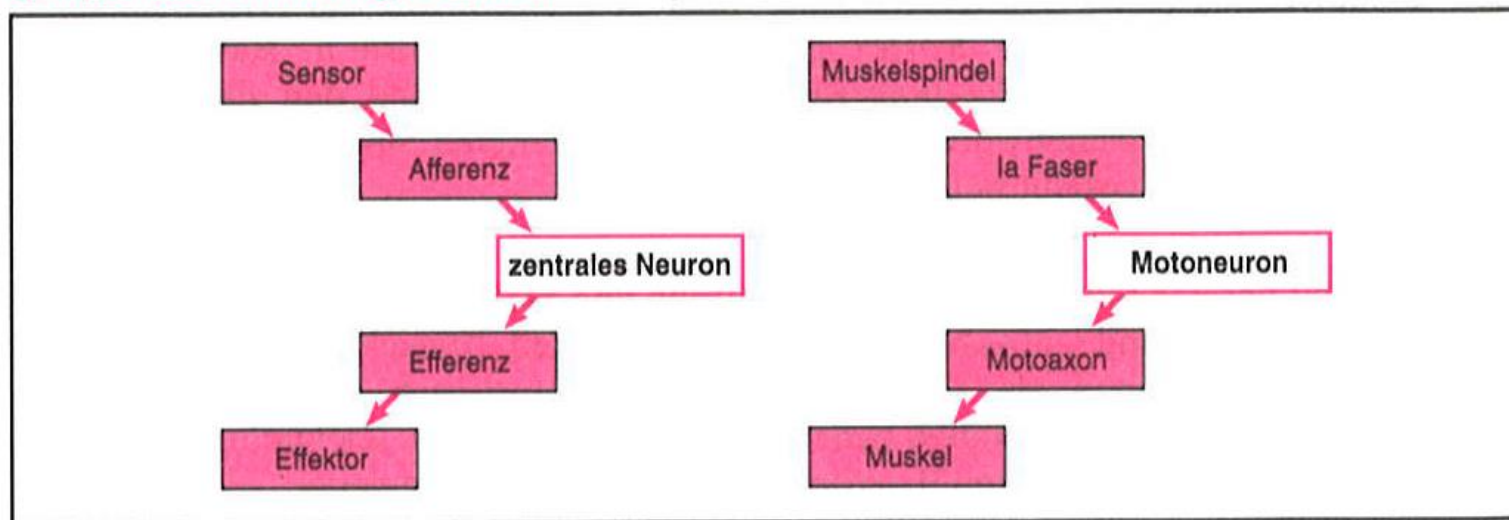




ation



Allgemeine Bezeichnungen der Anteile eines Reflexbogens und die Anteile des monosynaptischen Dehnungsreflexes



RF Schmidt: Memorix
Physiologie, 1992