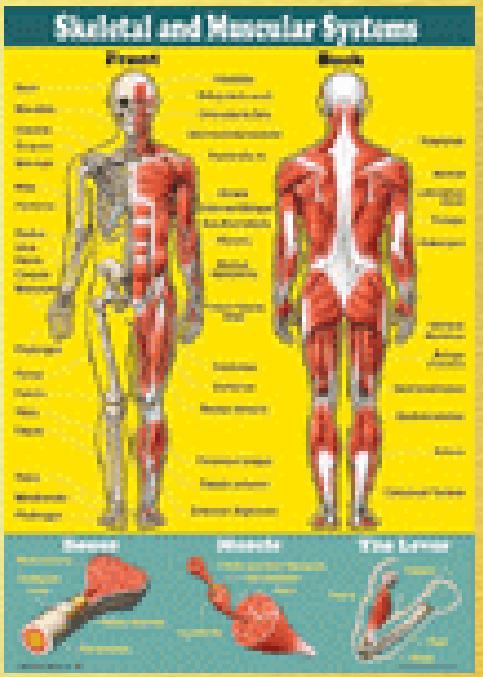
解剖學

-肌肉系統-



Structure of Skeletal Muscles

- 肌外膜 (epimysium)
  - 由肌腱延伸延伸出來
- 肌束 （fascicles)
  - 由肌外膜向內延伸將肌肉組織分隔
- 肌束膜 (perimysium)
  - 包圍肌束的外膜

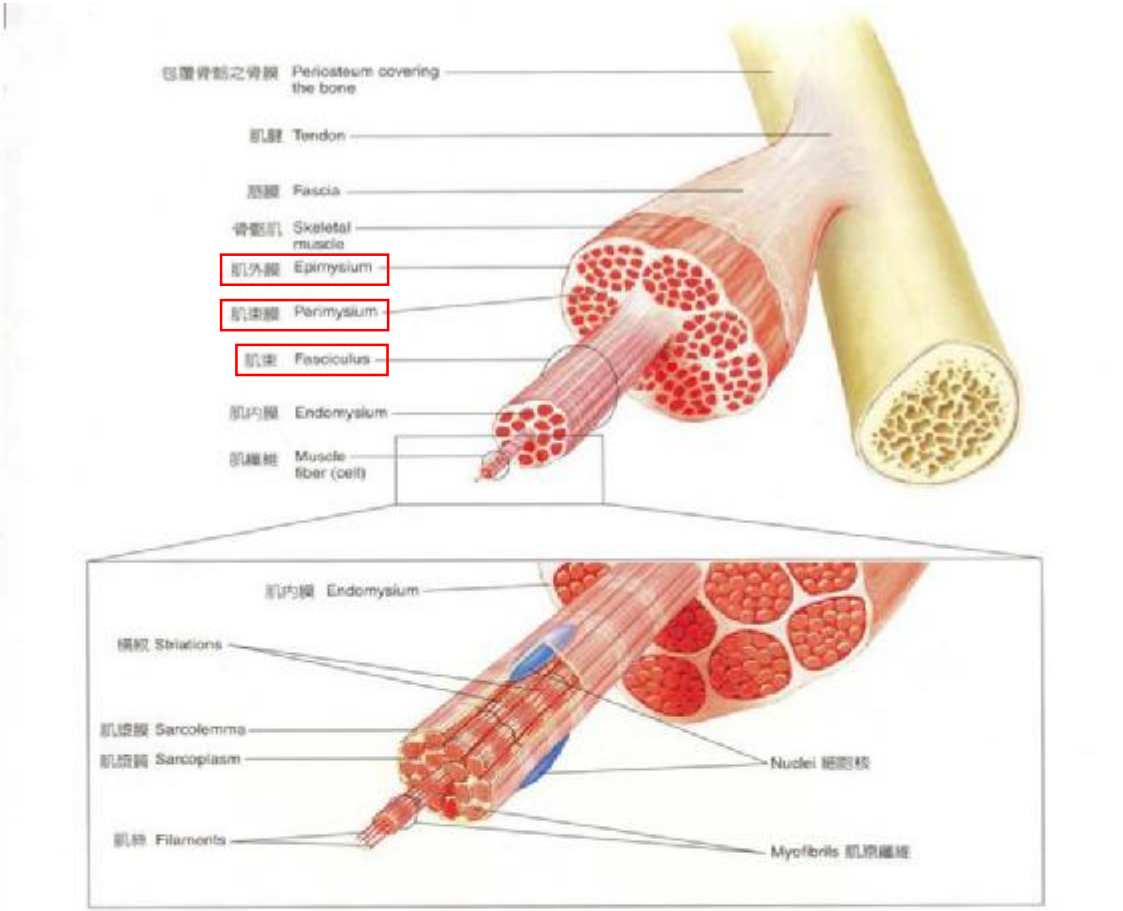


圖 12.1 骨骼肌的結構。上圖顯示肌纖維與肌腱、肌外膜、肌束膜及肌內膜等結締組織之間的關係，下圖為單一肌纖維之放大圖。

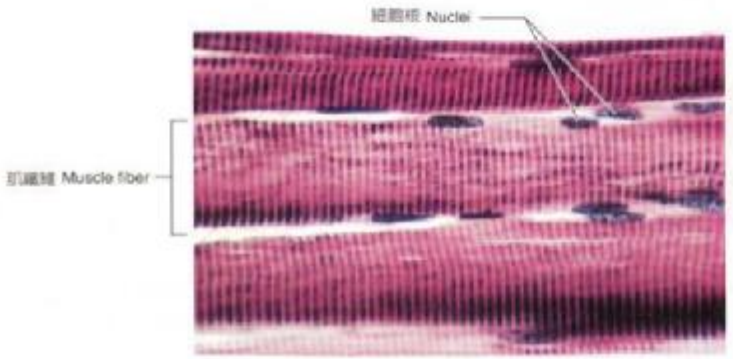
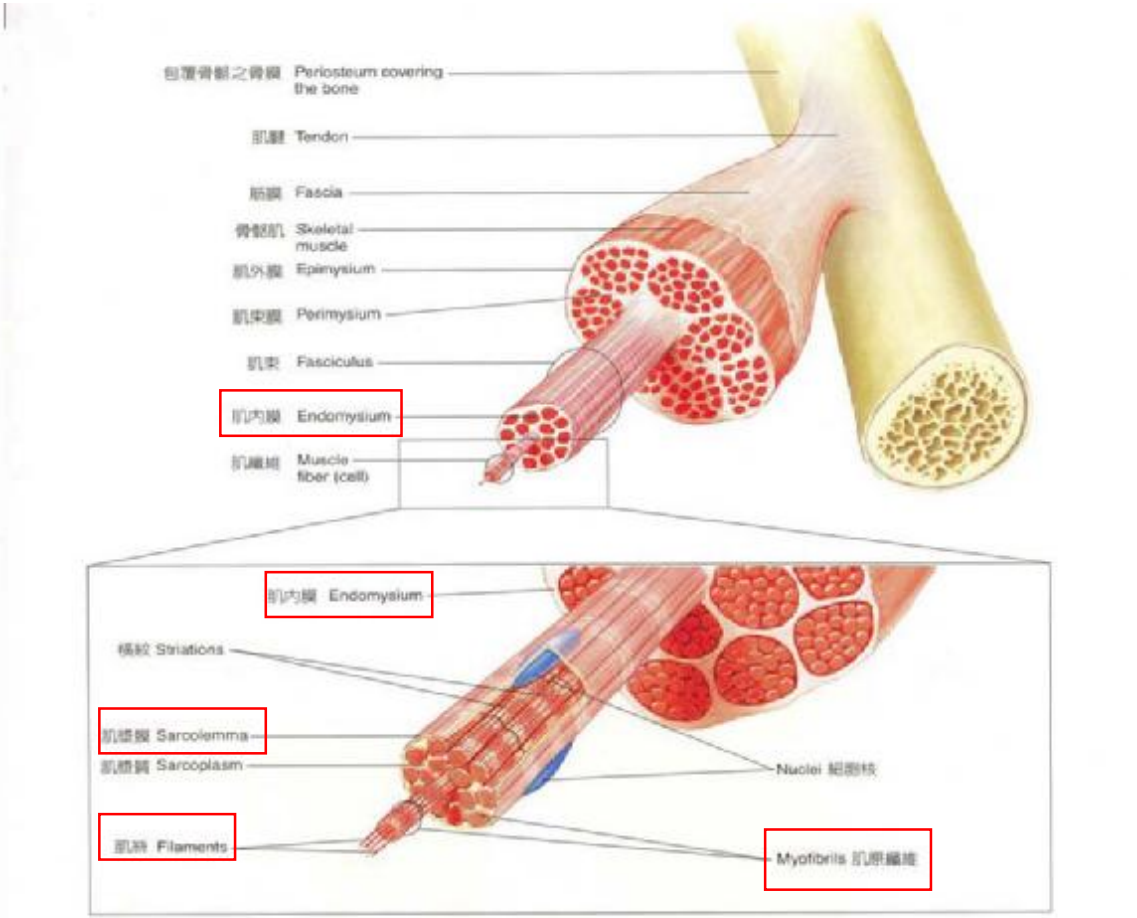


圖 12.2 光學顯微鏡底下所見肌纖維。其上的橫紋是由 A 帶及 I 帶交錯排列所形成（注意周圍的細胞核）。

Structure of Skeletal Muscles

- 肌漿膜 (sarcolemma)
  每條肌纖維外側之細胞膜
- 肌內膜 (endomysium)
  肌漿膜外側之結締組織
- 肌原纖維 (myofibrils)
- 肌絲 (filament)



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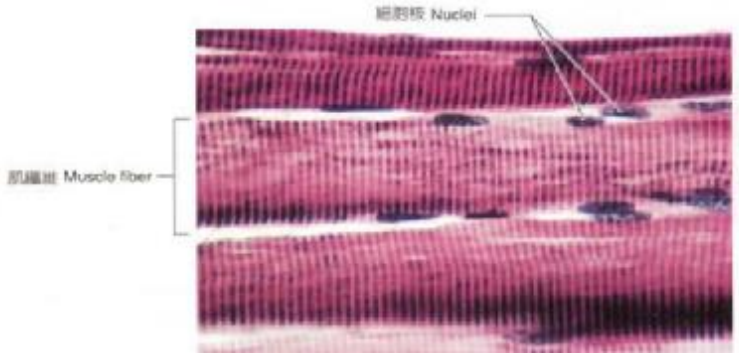


圖 12.2 光學顯微鏡底下所見的肌纖維。其上的橫紋是由 A 帶及 I 帶交錯排列所形成（注意周圍的細胞核）。

肌原纖維 (Myofibrils)

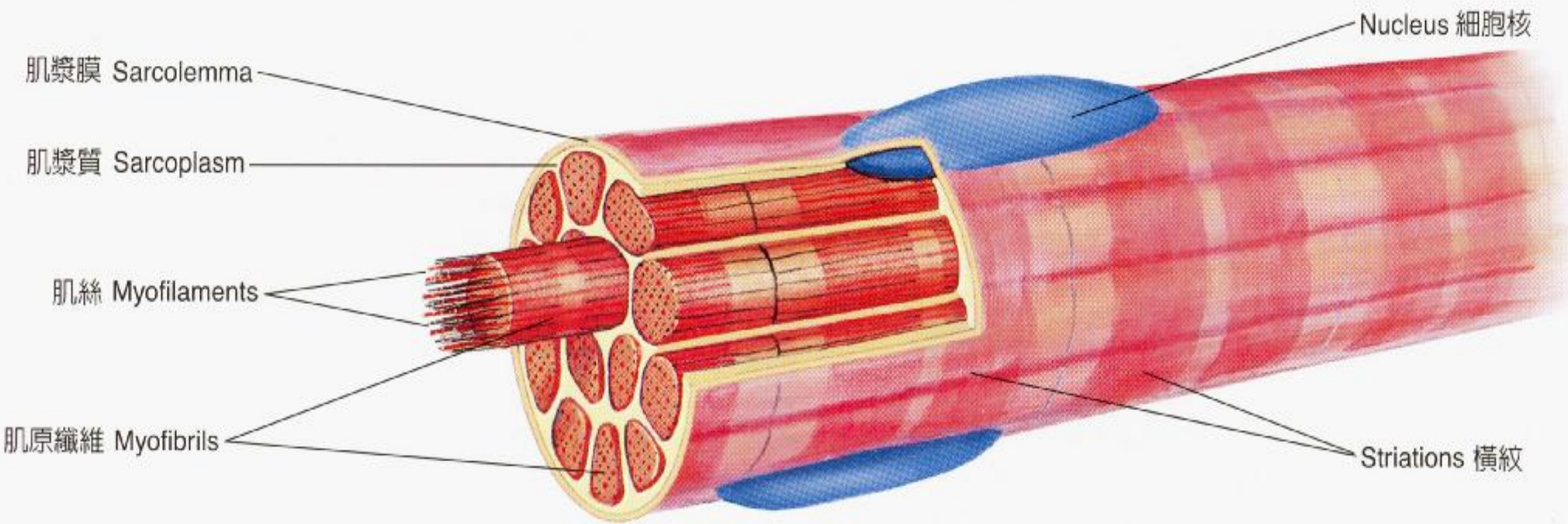


圖 12.5 **單一骨骼肌細胞的構造**。單一骨骼肌細胞由許多條含有肌動蛋白及肌凝蛋白絲的肌原纖維所構成。骨几具有橫紋，並且皆為多核的細胞。

tructure of Skeletal Muscles

- A band
- I band
- H zone
- Z disc
- 粗肌絲 (thick filament)
  - 肌凝蛋白 (myosin)
- 細肌絲 (thin filament)
  - 肌動蛋白 (actin)

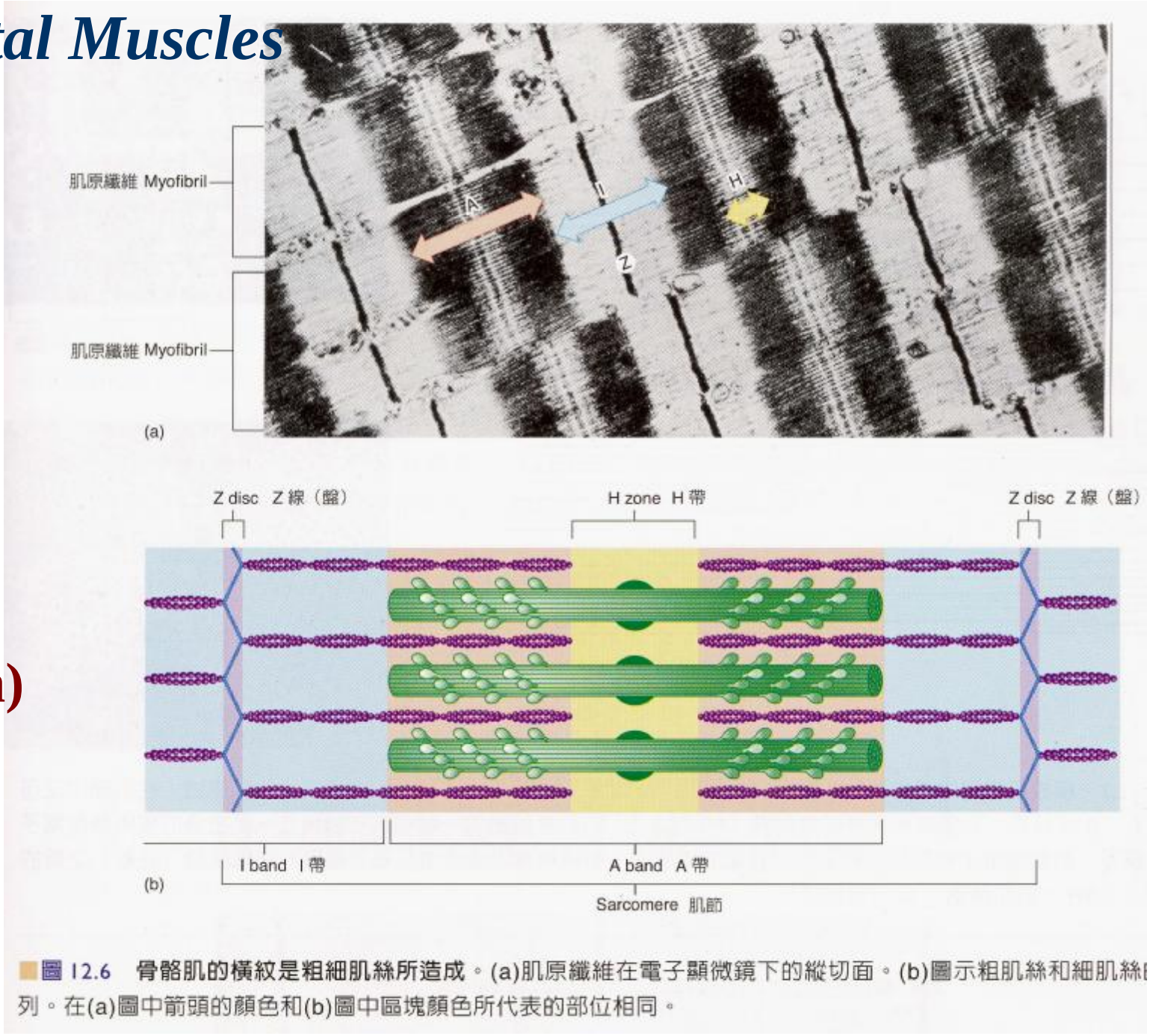
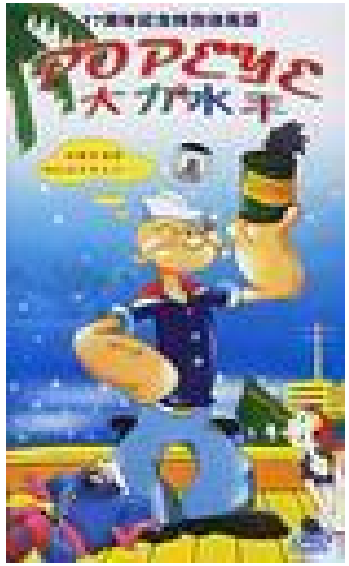
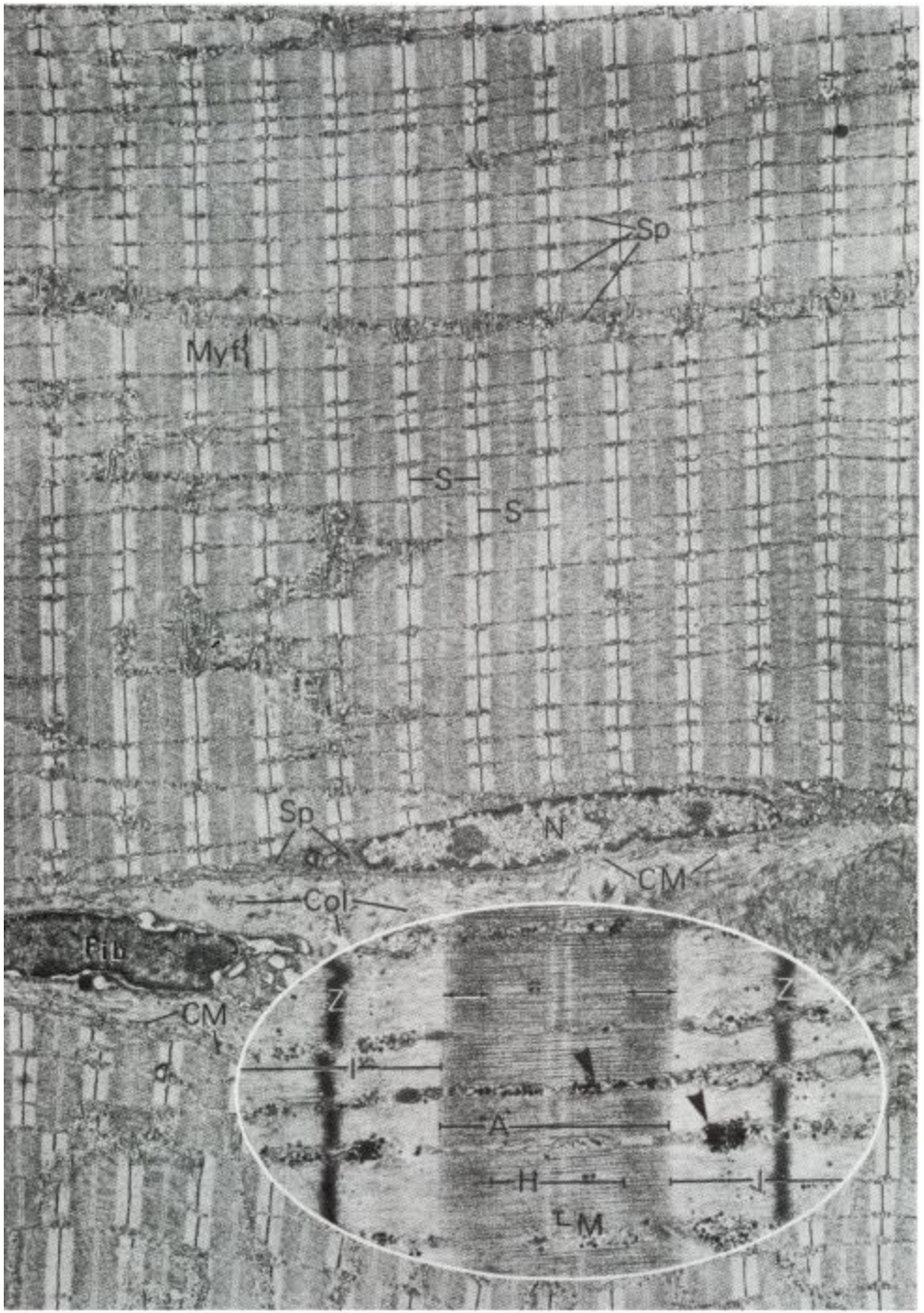


圖 12.6 骨骼肌的橫紋是粗細肌絲所造成。(a)肌原纖維在電子顯微鏡下的縱切面。(b)圖示粗肌絲和細肌絲的排列。在(a)圖中箭頭的顏色和(b)圖中區塊顏色所代表的部位相同。





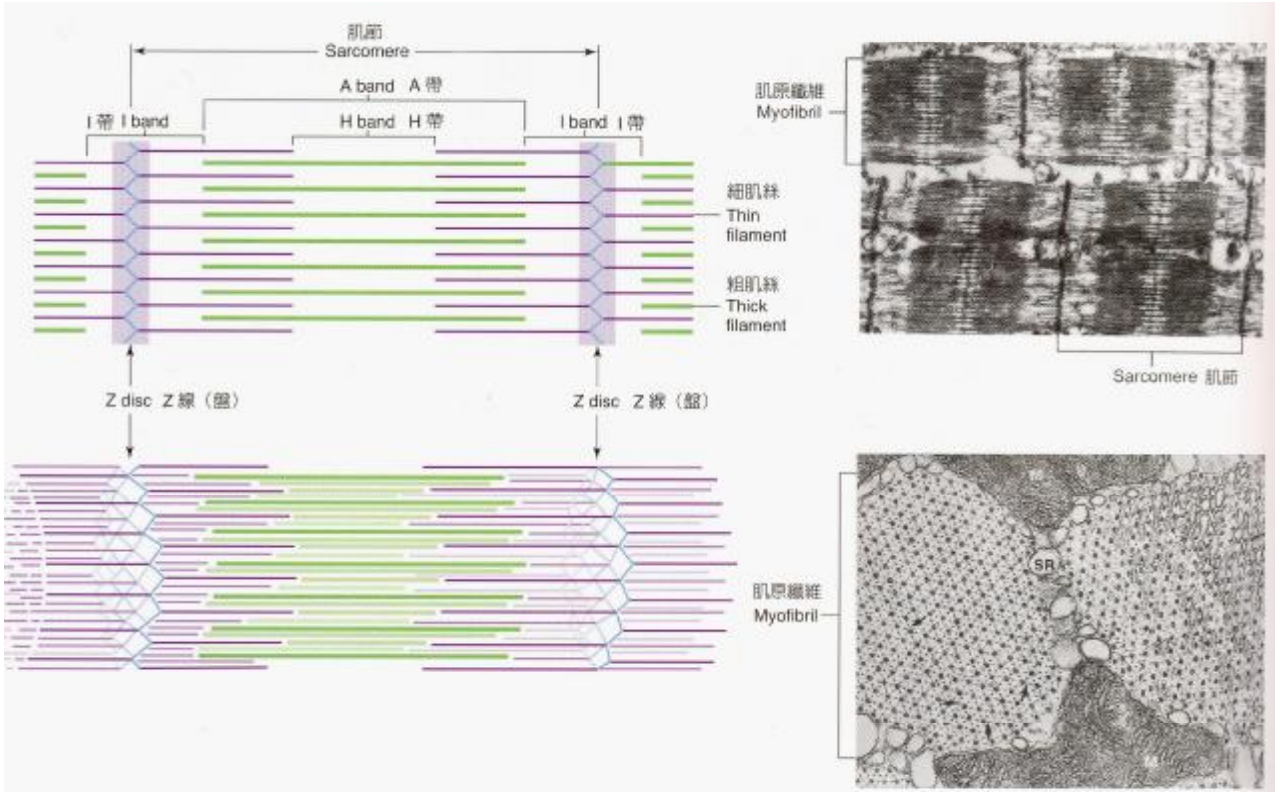


圖 12.7 **橫紋肌細胞內的粗肌絲和細肌絲的排列**。(a)將肌原纖維縱切，可看到有重複的肌節構造。在肌節中又可區分I、A和H區。右邊是相對應的電顯圖（53,000倍）。(b)是肌節的三度空間立體構造。而右邊的圖則是在電子顯微鏡下，肌原纖維中粗肌絲和細肌絲重疊處的橫截面。箭頭所指之處是粗肌絲（粗點）和細肌絲（細點）之間的橫橋。（SR＝肌漿質網；M＝粒線體）

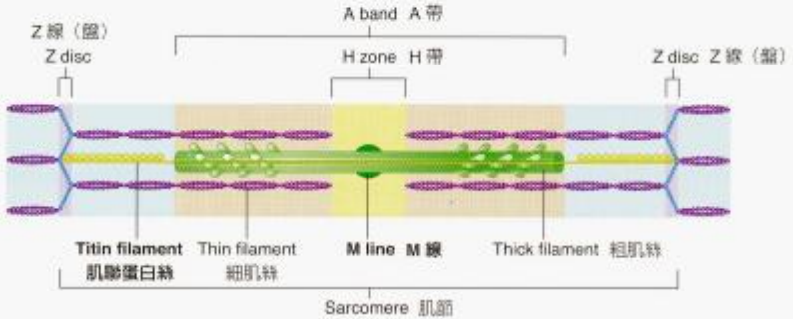


圖 12.8 **肌聯蛋白絲和M線**。M線是A帶中線的蛋白絲，可凝聚粗肌絲。肌聯蛋白是一種很長的彈性蛋白，其開始於M線，通過粗肌絲而終止於Z線。這些肌聯蛋白可穩固肌節裡的粗肌絲，並可協助使收縮的肌肉恢復長度。

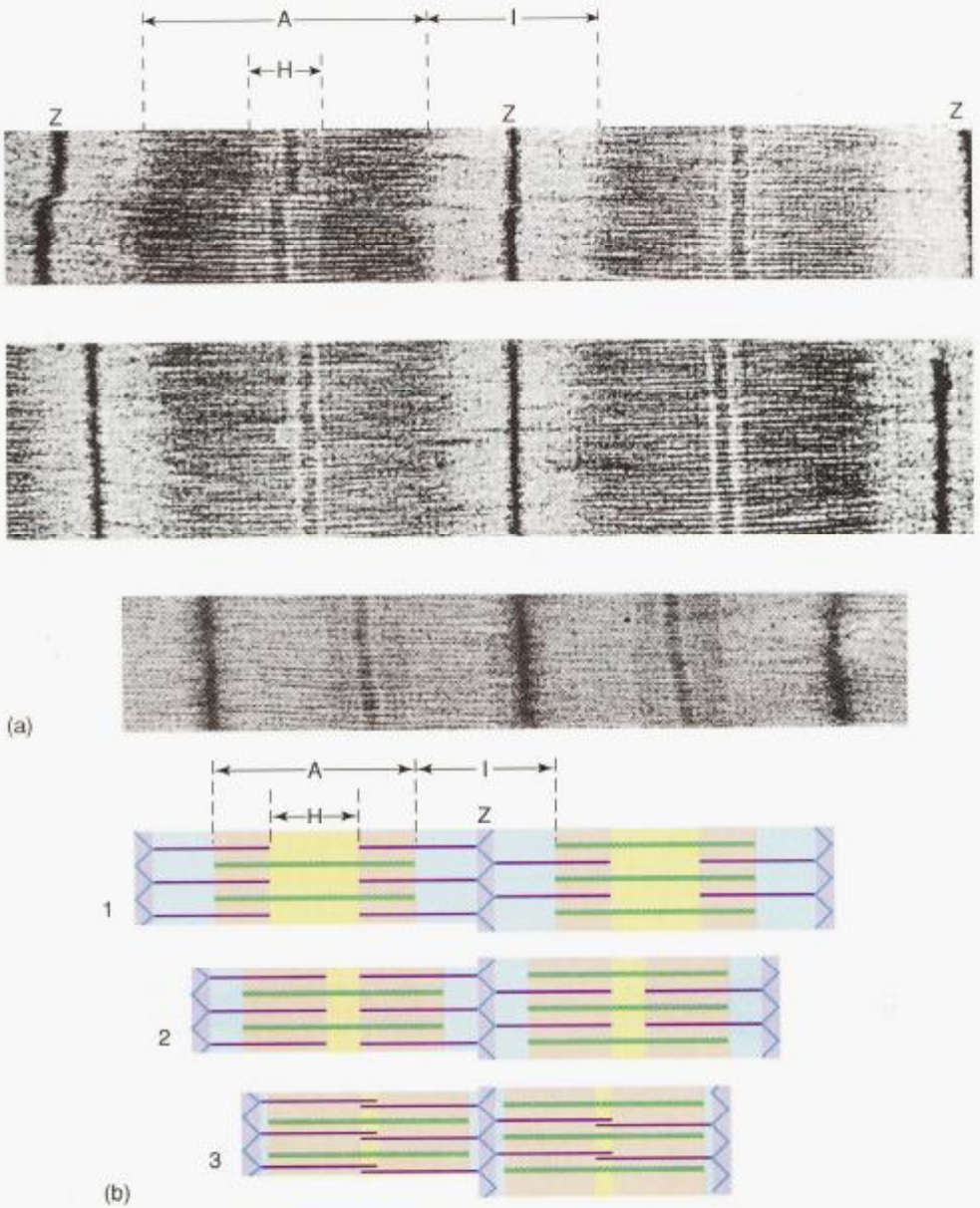


圖 12.9 肌肉收縮的肌絲滑動模型。(a)電子顯微鏡下所見的肌纖維，以及(b)肌肉收縮的肌絲滑動模型。當肌絲滑動時，Z 線互相靠近，肌節縮短。(1)鬆弛的肌肉；(2)部分收縮的肌肉；(3)完全收縮的肌肉。

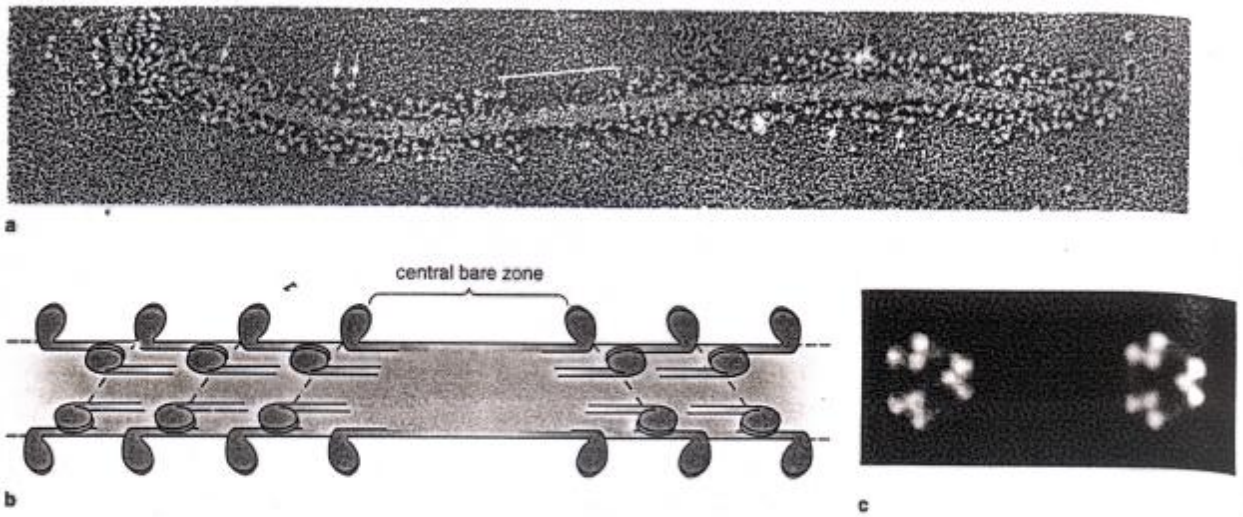
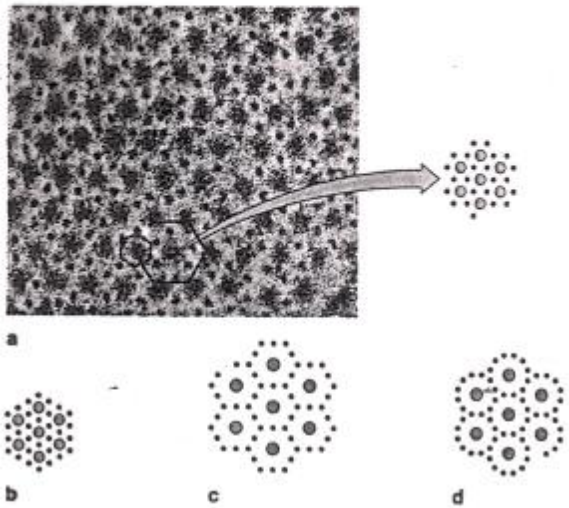


Figure 11-15 Thick filament structure. (a) A thick filament isolated from striated muscle, prepared for electron microscopy by negative staining. Myosin head units (arrows) are distributed all along the thick filament except for the central bare zone (bracket). × 116,000. (Courtesy of A. Elliott, from *J. Mol. Biol.* 131:133 [1979].) (b) The antiparallel or end-to-end arrangement of myosin molecules in thick filaments. (c) A composite, computer-averaged cross-sectional image of a thick filament from vertebrate striated muscle. The image shows the average density distribution of any superimposed thick filament cross sections. The density is reversed, so that regions of heaviest density appear lightest in the image. The image shows nine subunits, indicating that the tails of nine myosin molecules associate to form a thick filament. (Courtesy of F. A. Pepe.)



◀ **Figure 11-16** Arrangement of thick and thin filaments in sarcomeres. (a) Vertebrate sarcomere in a cross section made in the region of overlap between thick and thin filaments. The filaments form a double hexagon pattern (dotted lines). Each thick filament is surrounded by six thin filaments arranged hexagonally, and the thick filaments make up a larger hexagon. × 115,000. (c) The arrangement of thick and thin fibers in insect flight muscle and various other arthropod muscles (c and d). (Micrograph courtesy of H. E. Huxley, with permission from *J. Mol. Biol.* 37:507 [1968]. Copyright by Academic Press, Inc. [London] Ltd. Diagrams courtesy of F. A. Pepe; reproduced from *J. Cell Biol.* 37:445 [1968], by copyright permission of the Rockefeller University Press.)

細肌絲

- 肌動蛋白 (actin)
- 旋轉肌球素 (tropomyosin)
  - 1. TnT
  - 2. TnC
  - 3. TnI

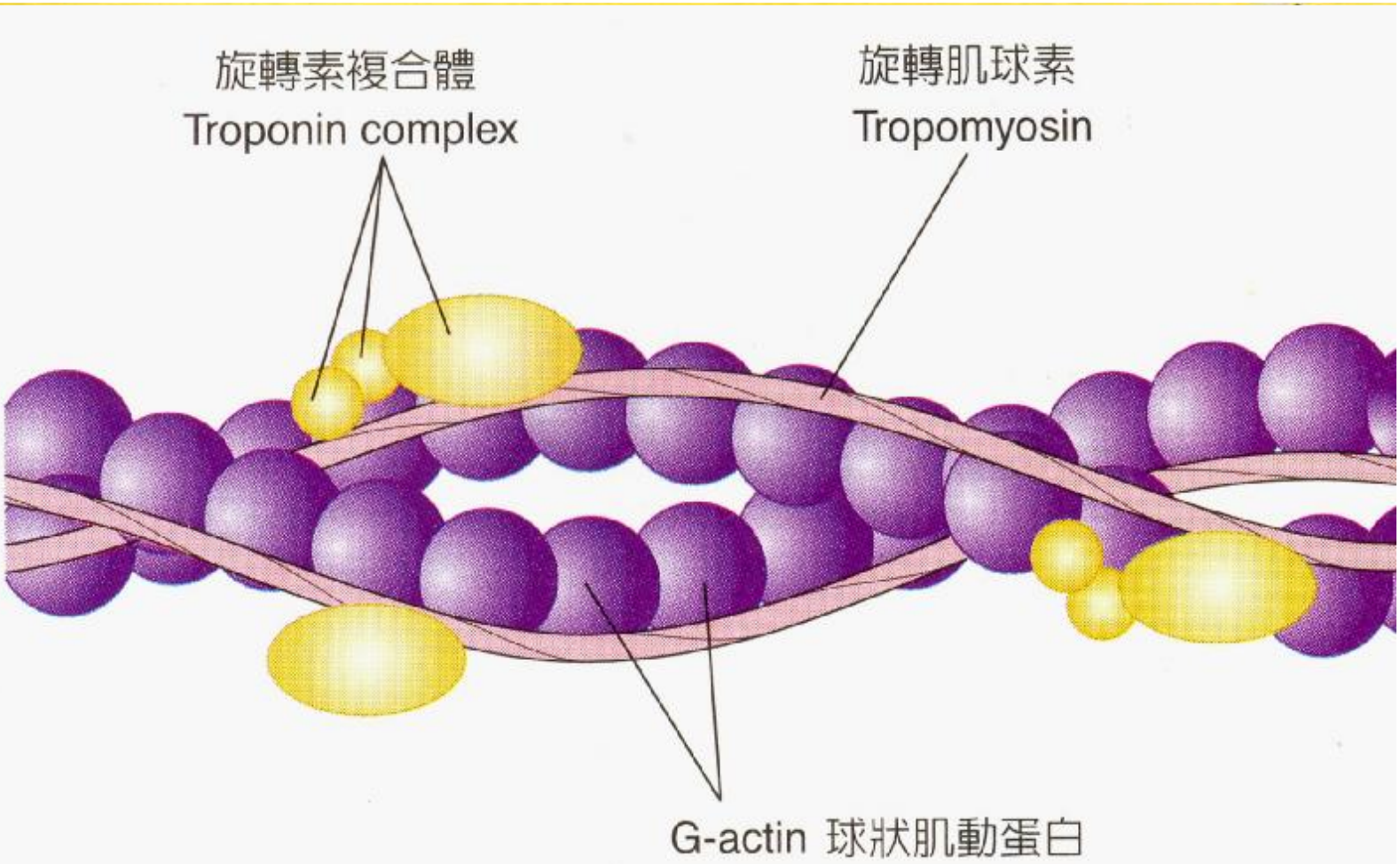


圖 12.13 細肌絲上旋轉素、旋轉肌球素和肌動蛋白的相對位置。旋轉肌球素附著於肌動蛋白之上，而旋轉素複合體所包含的 3 個次單位則直接附著於旋轉肌球素上（不直接附於肌動蛋白上）。

粗肌絲

- 1. 肌凝蛋白ATP水解酶 (ATPase)
- 2. 橫橋 (cross bridges)

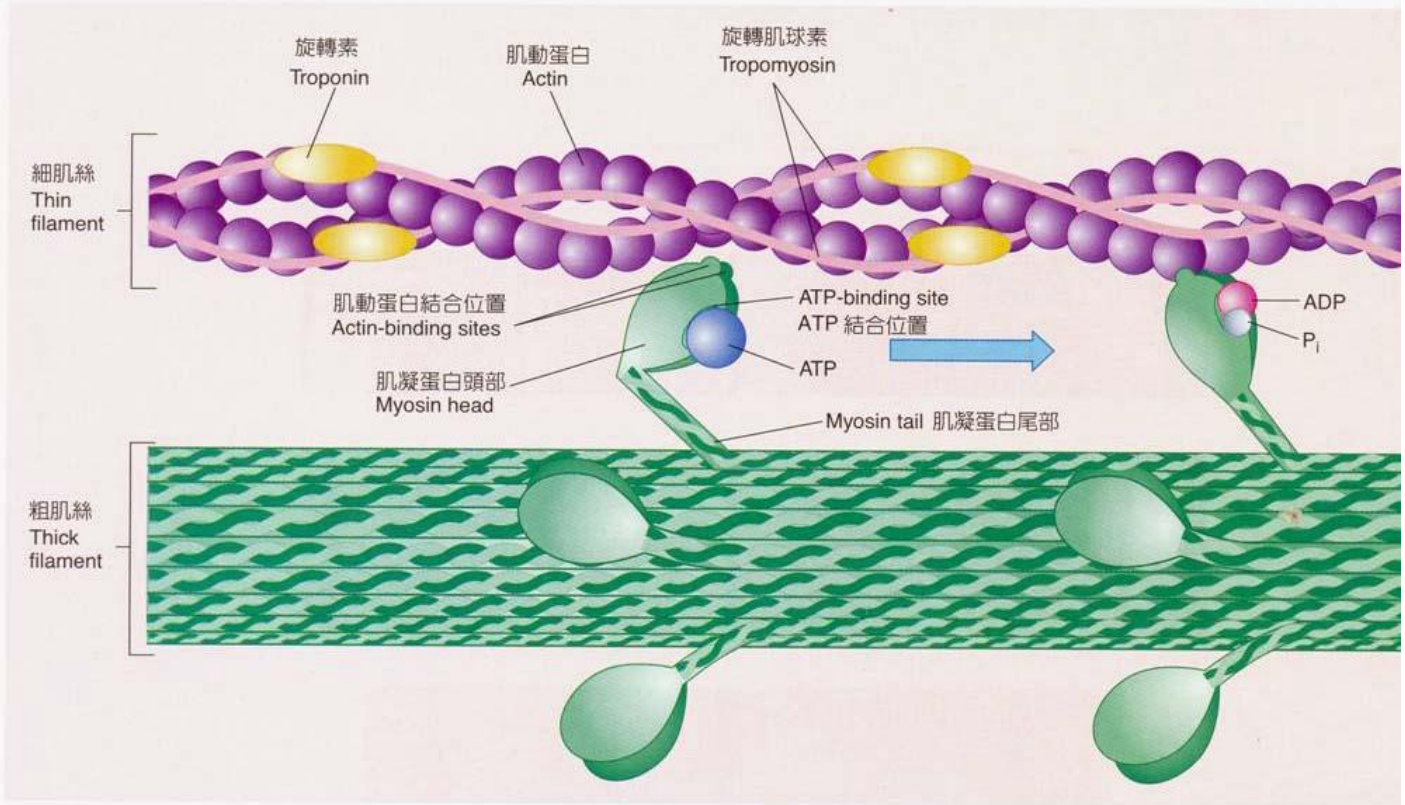


圖 12.10 肌凝蛋白的構造，顯示其與 ATP 和肌凝蛋白結合的位置。當肌凝蛋白頭部與 ATP 結合，然後水解 ADP 和磷酸根離子(P_i)。這動作促使肌凝蛋白頭部豎起，並附著在肌動蛋白上面。

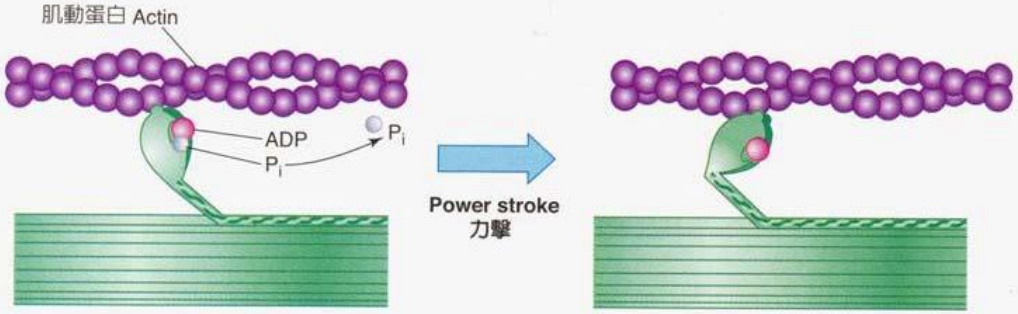


圖 12.11 橫橋的力擊。在肌凝蛋白的頭部結合上肌動蛋白之後，磷酸根離子被釋放出來。這引起肌凝蛋白頭結構的改變因而造成力擊。而此力擊引起粗、細肌絲間互相的滑動。

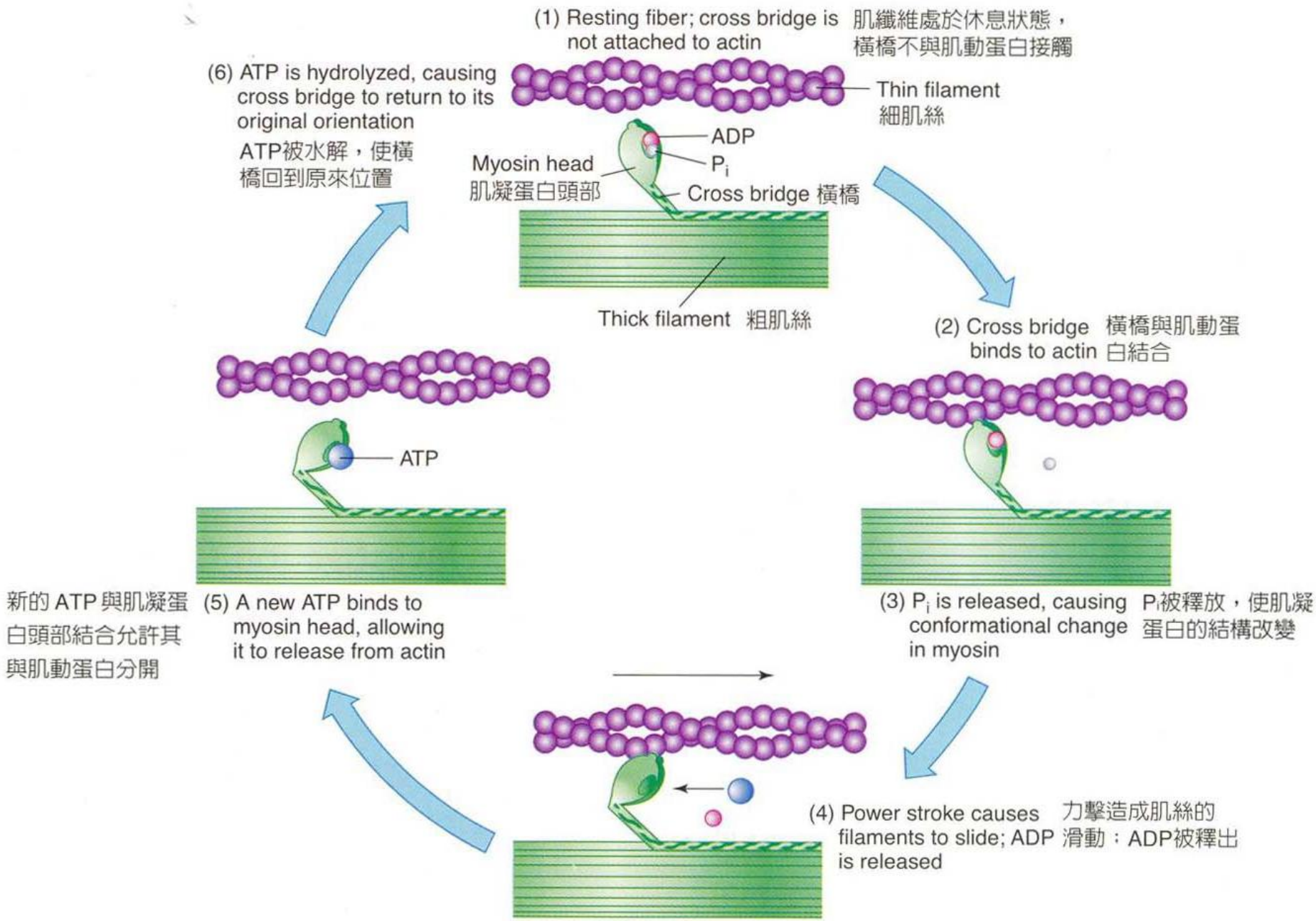


圖 12.12　造成肌絲滑動及肌肉收縮的橫橋循環。 ATP 水解是活化橫橋所必需的條件，力擊結束後，橫橋與肌動蛋白分開前，必須有新的 ATP 與其結合，才能使兩者完全分開。

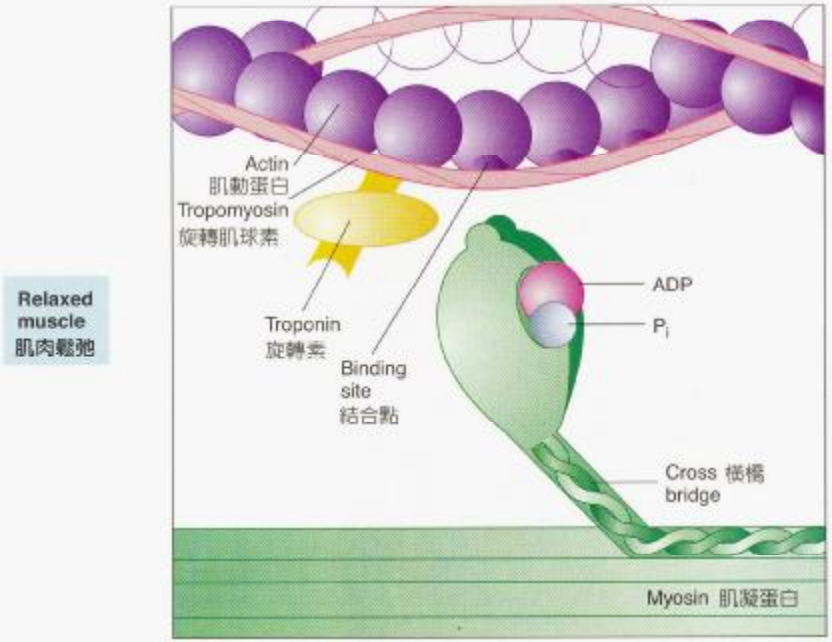


圖 12.14 Ca^{2+} 在肌肉收縮時所扮演的角色。Ca^{2+} 與旋轉素的結合造成旋轉素－旋轉肌球素複合體的移動，露出肌動蛋白上的橫橋結合位置。此時橫橋則與肌動蛋白結合而產生力擊。

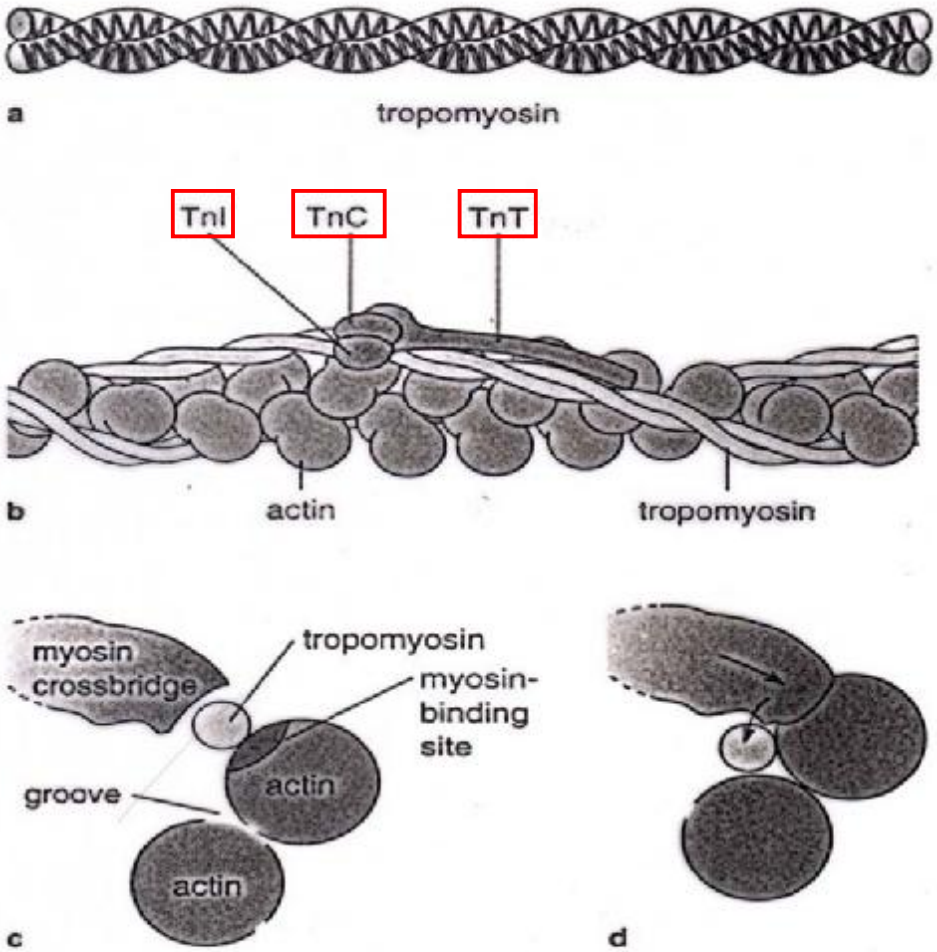


Figure 11-10 Actin-linked muscle regulation by the troponin-tropomyosin complex. (a) The coiled-coil structure of tropomyosin. (b) The arrangement of tropomyosin and the TnC, TnI, and TnT subunits of troponin on striated muscle microfilaments. (c) and (d) The actin-linked control mechanism as seen in a cross section of a microfilament (see text). In the blocking position (c), tropomyosin covers the binding site, or myosin crossbridges on the actin subunits. Movement of tropomyosin toward the microfilament groove (d) exposes the myosin binding sites and triggers the crossbridging cycle.

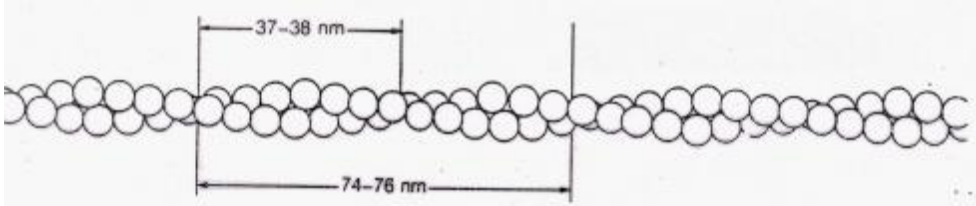


Figure 8-13 The linkage of actin molecules to form a microfilament. Each spherical unit in the double spiral is an actin molecule.

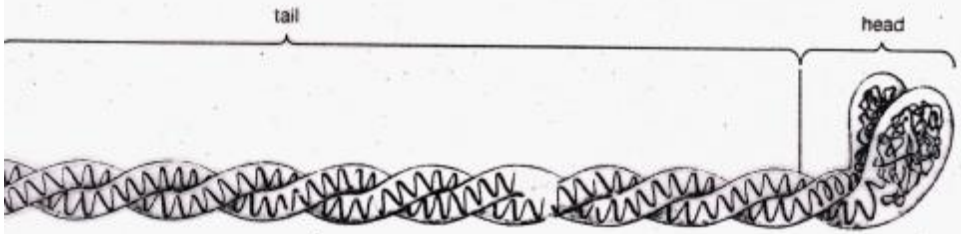
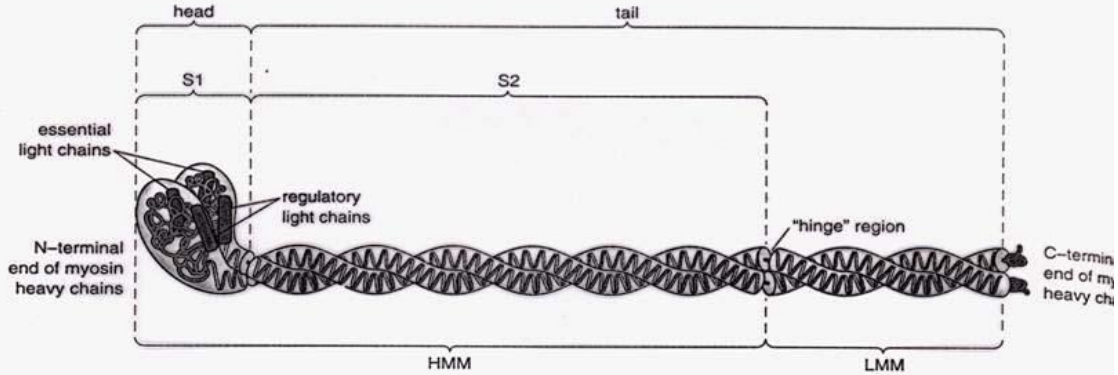


Figure 8-14 Structure of a myosin molecule. Two polypeptide chains wind together to form the double head and spiraled tail of the molecule.



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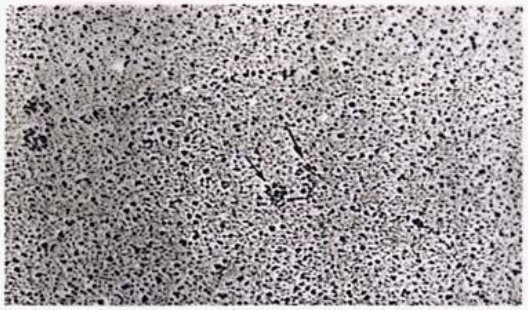

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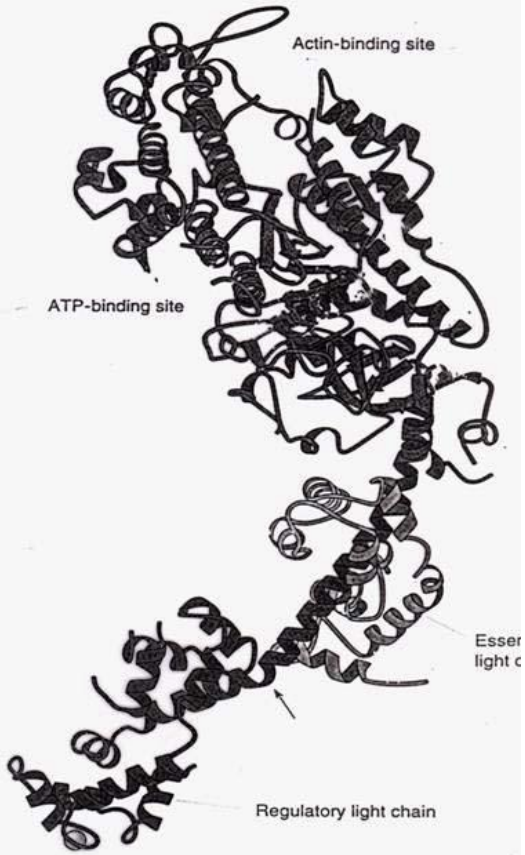
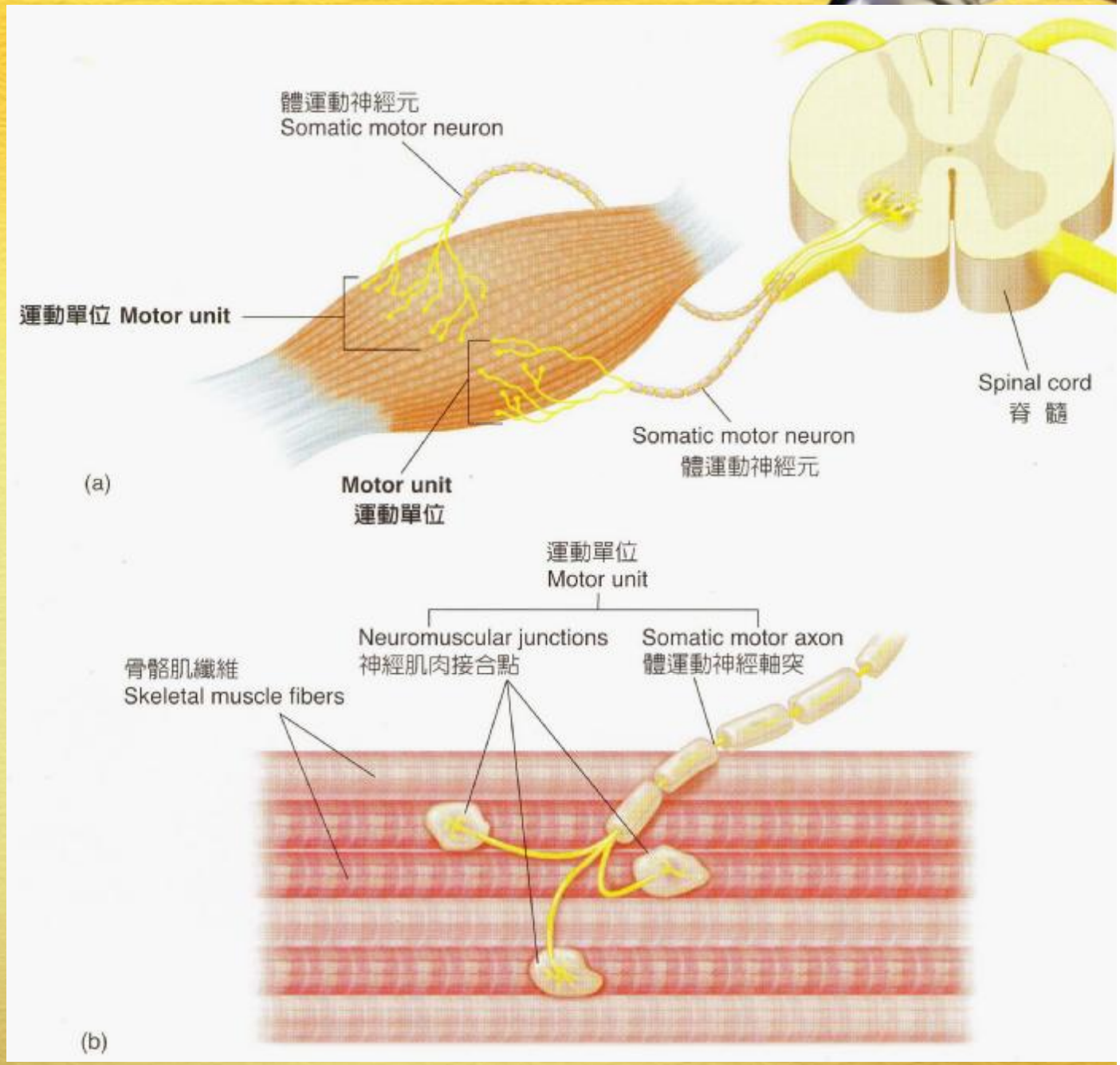


Figure 11-8 **(a)** Myosin II structure. Two myosin heavy chains wind into a coiled-coil structure to form the tail and into a less regular conformation to form the double head structure. One essential and one regulatory myosin light chain are also present in each subunit of the double head structure. HMM (heavy meromyosin), LMM (light meromyosin), S1, and S2 are fragments produced by protease digestion of myosin molecules. **(b)** Myosin molecules isolated from chicken skeletal muscle and prepared for electron microscopy by freeze-drying and shadowing. The tail and double head structure (arrows) are visible. (Courtesy of T. Wallimann, from *Eur. J. Cell Biol.* 30:177 [1983].) **(c)** Structure of the S1 head unit of myosin II as deduced from X-ray diffraction. One of the unusual features of the head unit is the long alpha helix (arrow) that extends through much of the structure. The essential light chain may stabilize this helix. (Courtesy of I. Rayment and the AAAS, from *Science* 261:50 [1993].)

運動單位
(*Motor unit*)

- 定義：每一條運動神經元與其所支配的肌纖維（肌細胞



運動單位
(*Motor unit*)

- 運動神經元
- 運動終板
  (motor end plate)
- 骨骼肌的肌纖維

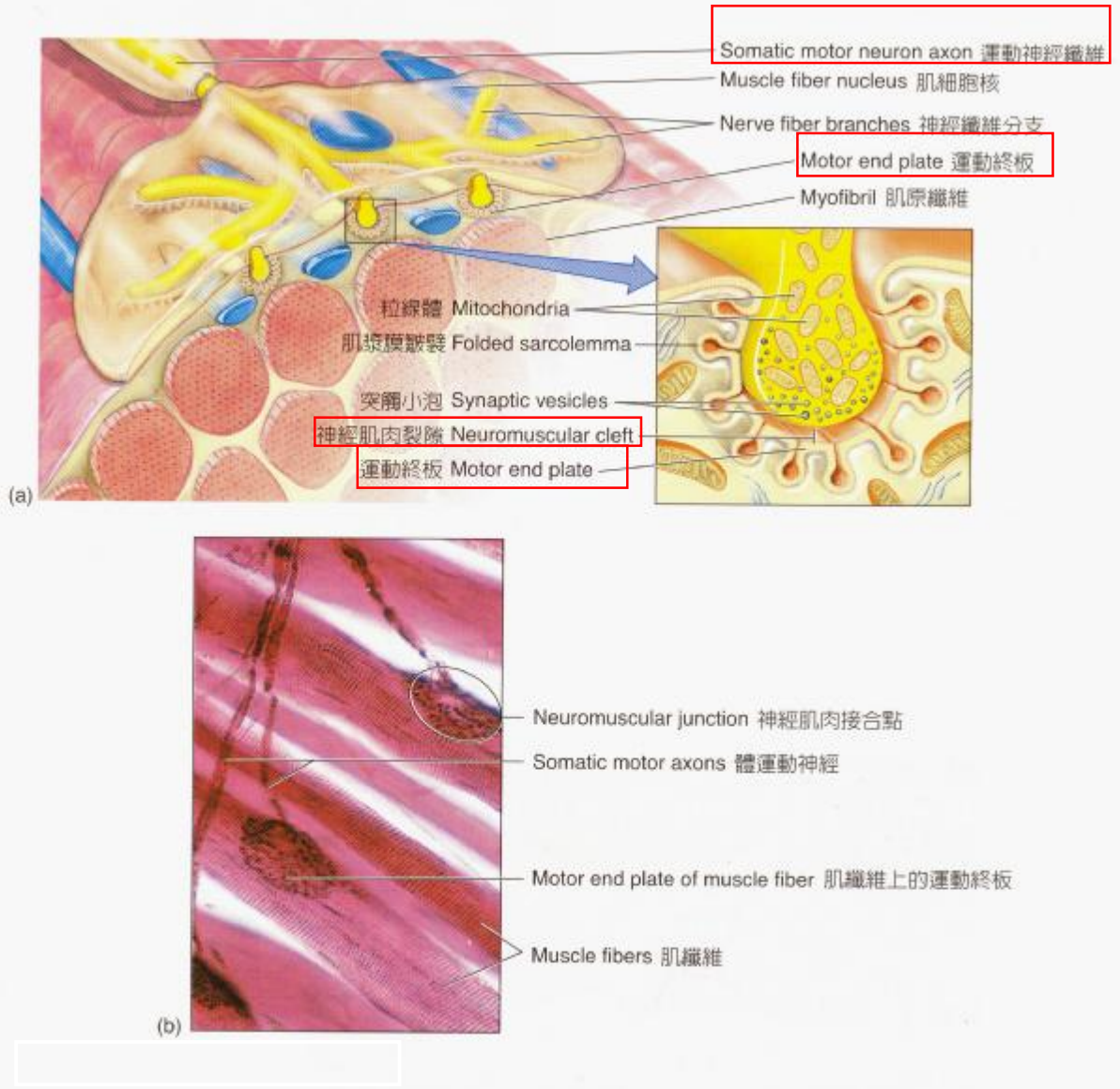


圖 12.3 神經肌肉接合點上的運動終板。神經肌肉接合點即神經和肌肉之間的突觸。運動終板為圍繞於軸突之肌纖維膜上的特化區域。(a)圖示神經肌肉接合點。注意軸突和肌肉細胞之間有小間隙。(b)肌肉和神經肌肉接合點的照片。

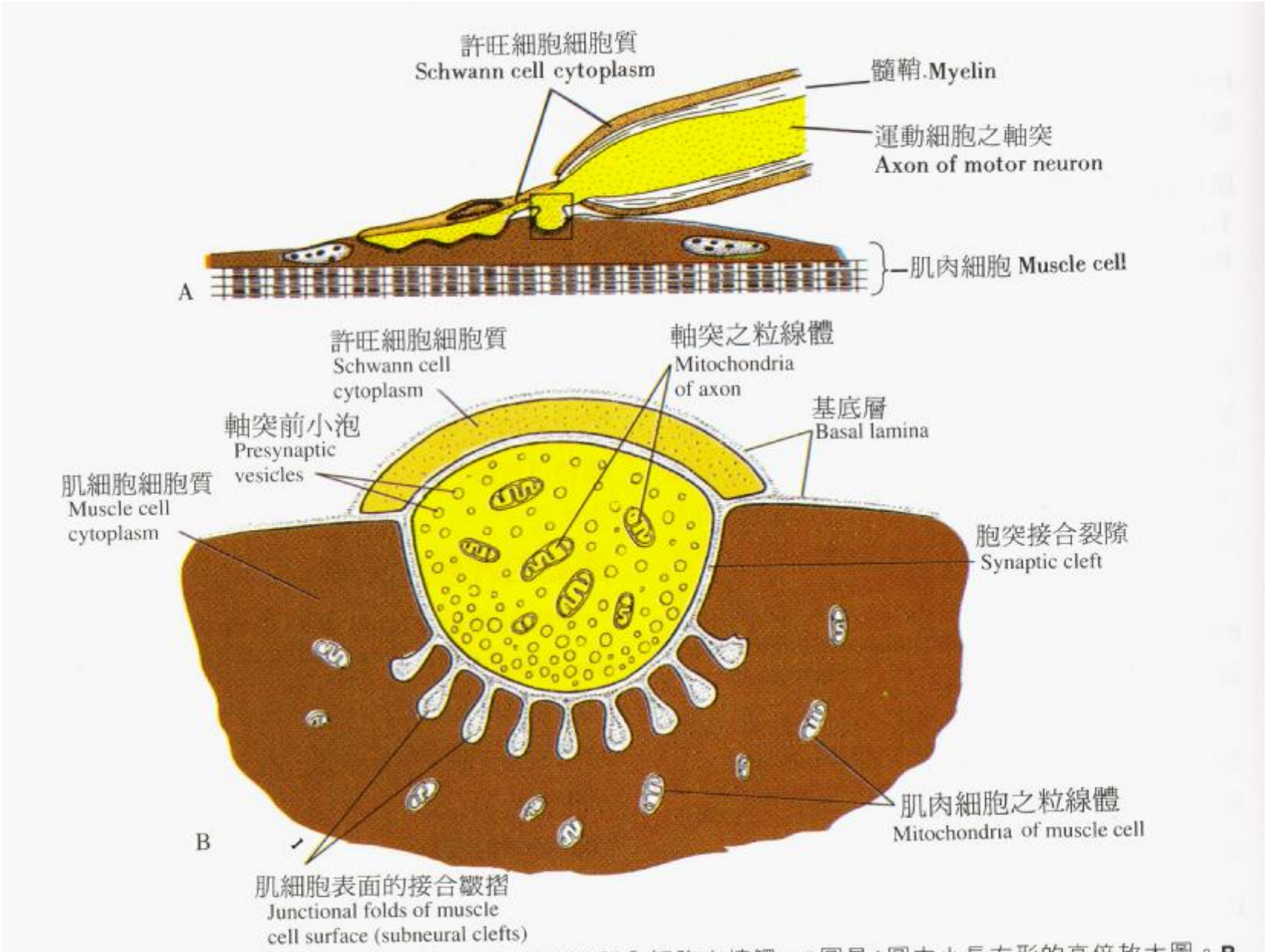


圖10.8 **A.**神經肌肉接合處之示意圖。可見軸突與肌肉細胞之接觸。B圖是A圖中小長方形的高倍放大圖。**B.** 請注意肌肉細胞的接合皺褶可使接合裂隙內的表面積變大。基底層(basal lamina)會舖滿整個裂隙。圖中可見許旺細胞的細胞質覆蓋著軸突末端。

圖 10.4　神經肌肉接合

(A)掃瞄式電子顯微鏡下的運動神經纖維終端。軸突終端可分佈到數條肌纖維上並且在肌纖維的表面形成平坦的運動終板。×1000。(B)神經肌肉接合處的簡圖。(C)運動終板的細微構造。(D)肌肉纖維的肌漿膜和軸突終端之間的突觸裂。放大圖。(E)電子顯微鏡下的神經肌肉接合處，×17,400

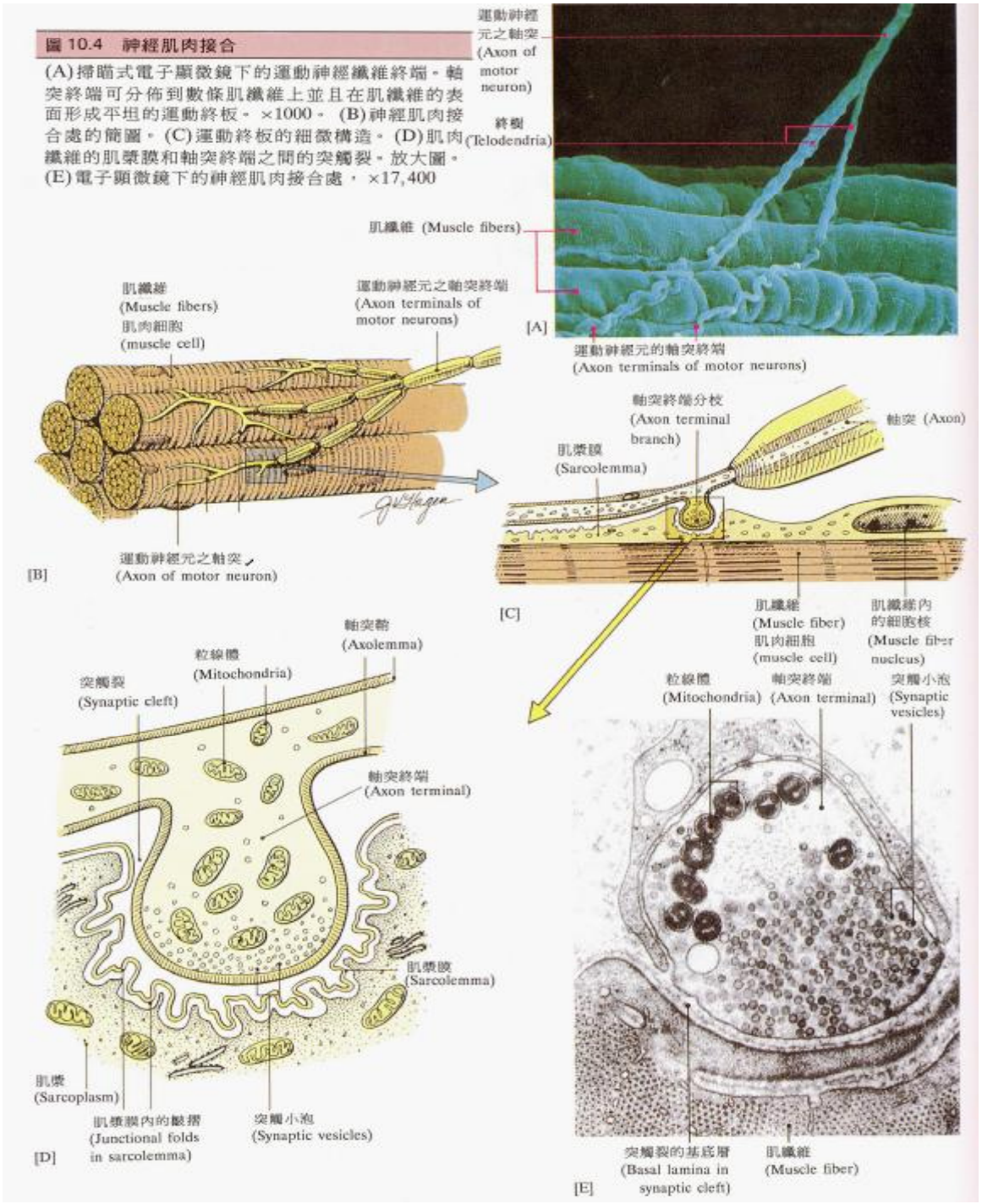
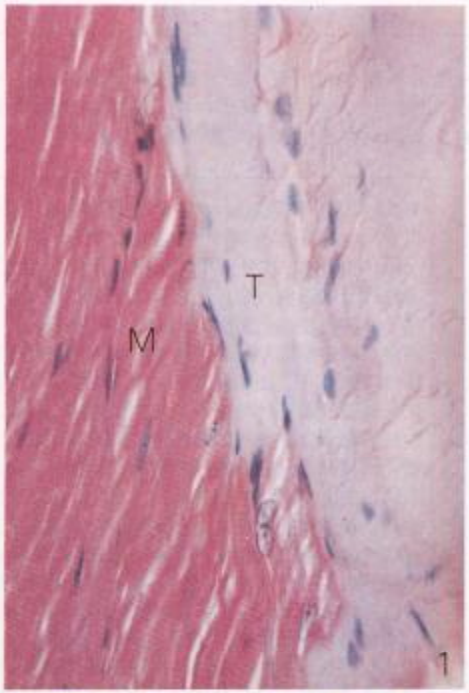
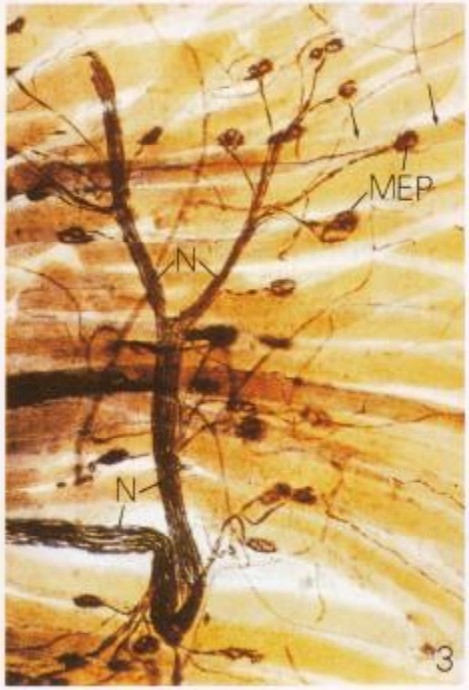


圖10.8　C. 一個運動終板的電子顯微鏡圖，顯示軸突末端位於一條骨骼肌纖維的突觸裂隙(synaptic cleft)內。它顯示了粒線體(M)的聚集，以及許多突觸小泡(SV)。運動軸突末端沒有與肌纖維接合物的部分，被許旺細胞(S)所包圍，但並沒有髓鞘(myelin)出現，肌纖維呈現接合皺襞(JF)及位於其間的神經下裂(subneural clefts, SnC)。肌纖維的基底板是赤裸於神經下裂之內。在終板部位的其他構造，則有肌纖維內聚集的粒線體(M)，肌纖維的核(N)，以及一些肌微纖維(MF)。



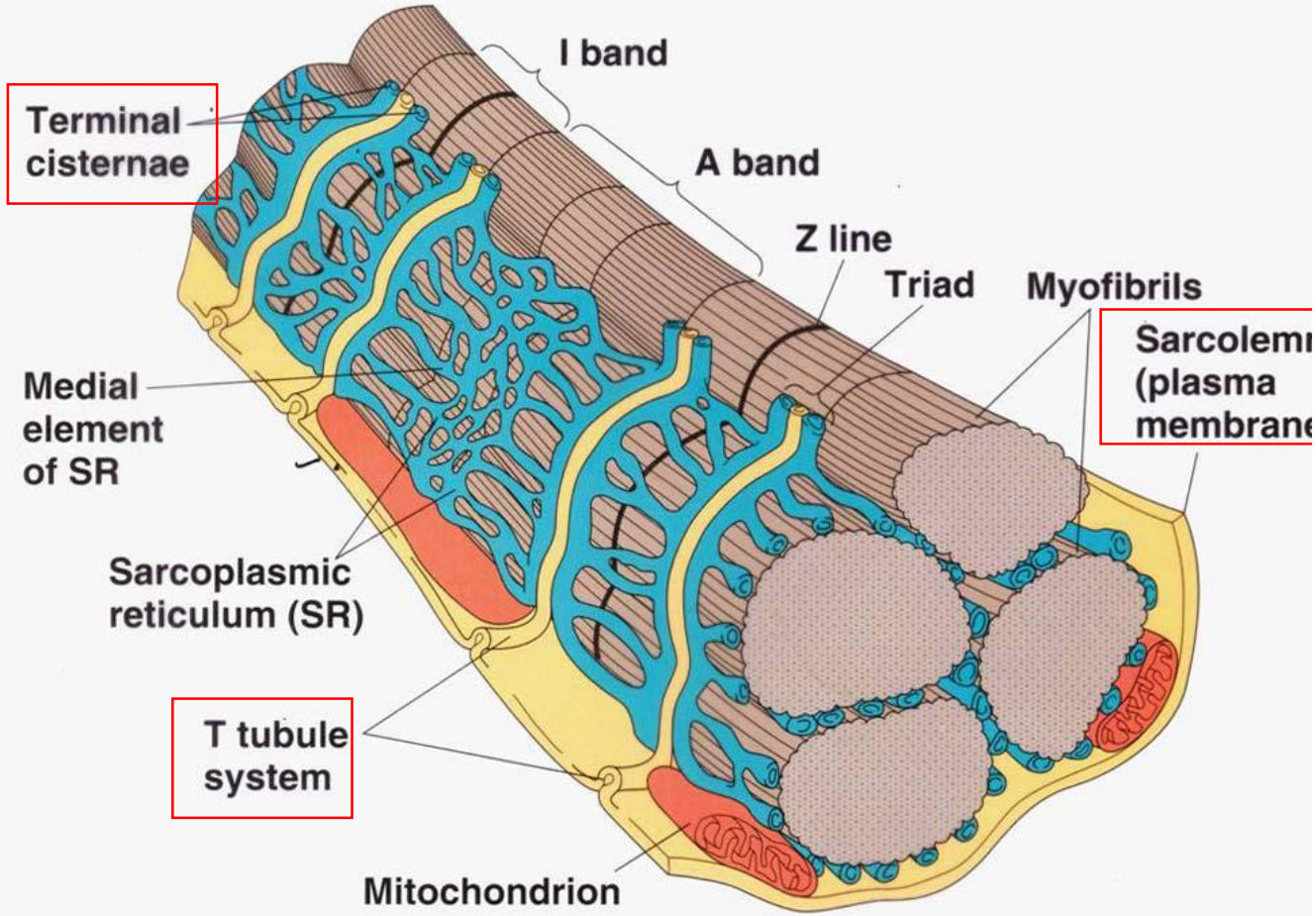


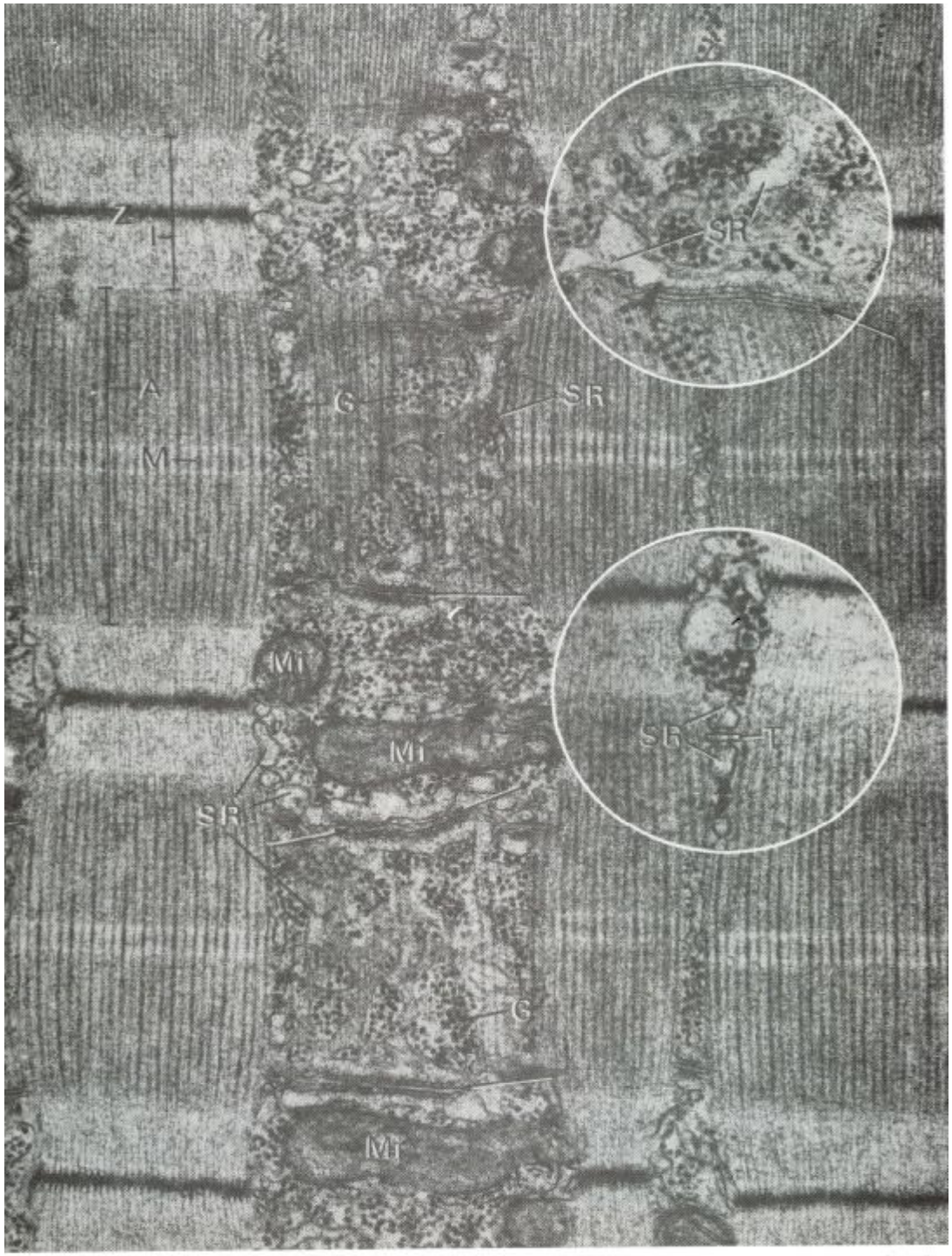
第十章 肌肉組

肌漿質網
(*Sarcoplasmic Reticulum*)

- 肌漿膜 (Sarcolemma)
- T-tube (橫小管)
  (Transverse tube)
- 終池 (Terminal cisternae)

Figure 21-15 The Sarcoplasmic Reticulum and the Transverse Tubule System of Skeletal Muscle Cells





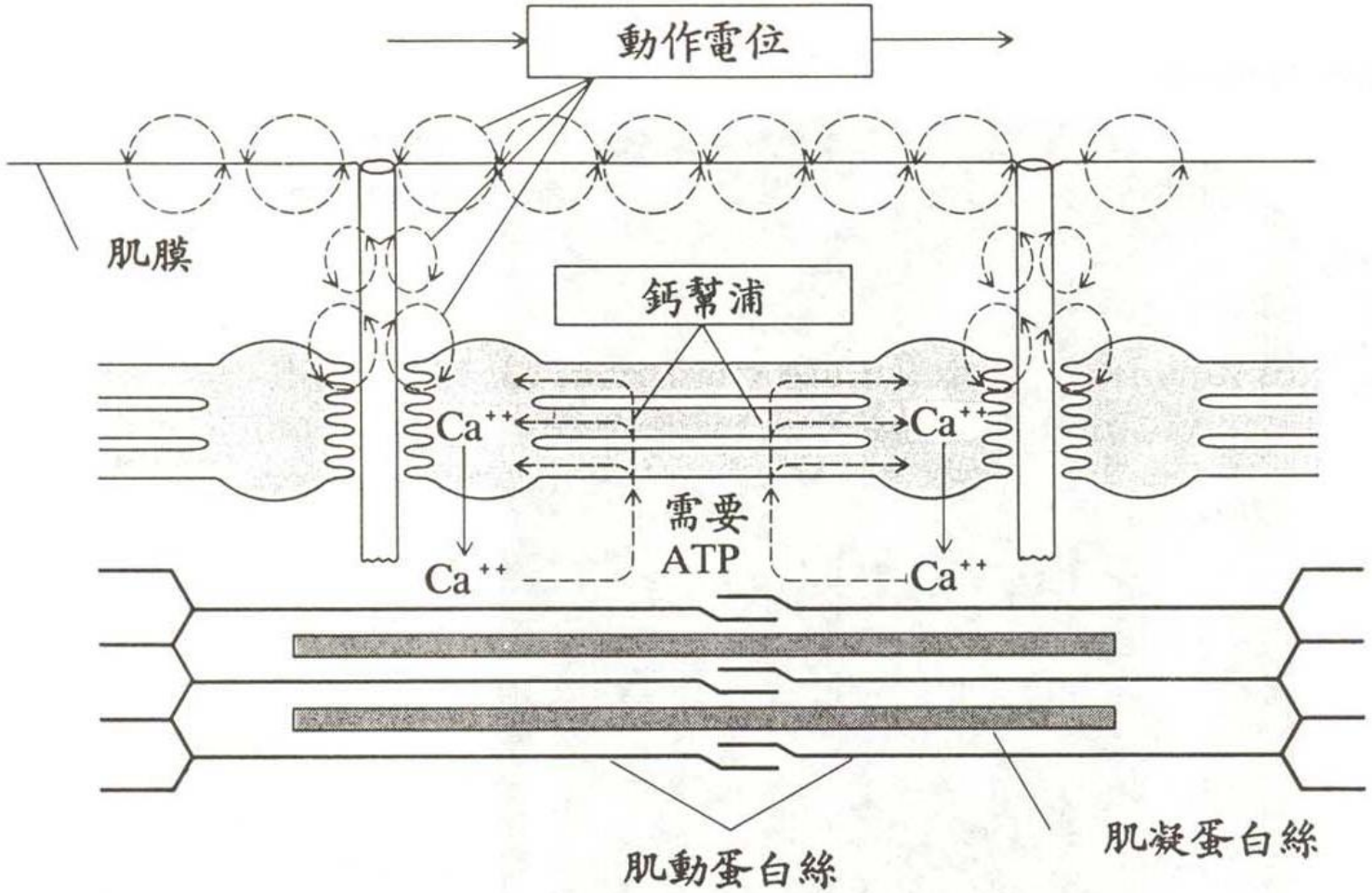


圖6-10　肌肉的興奮及收縮聯合。顯示動作電位引起肌漿質網釋放鈣離子，而後鈣幫浦再將鈣離子吸收回去。

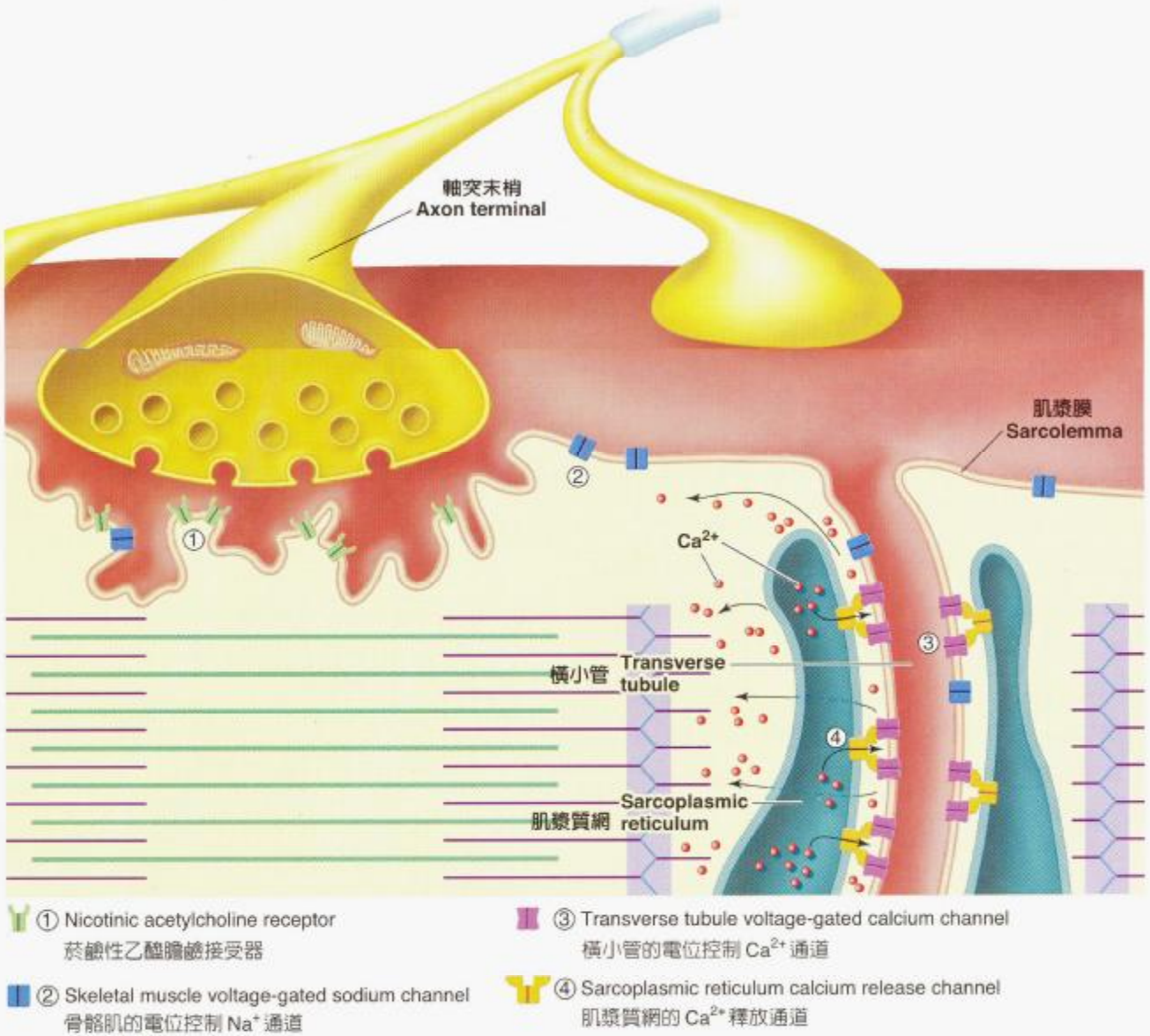
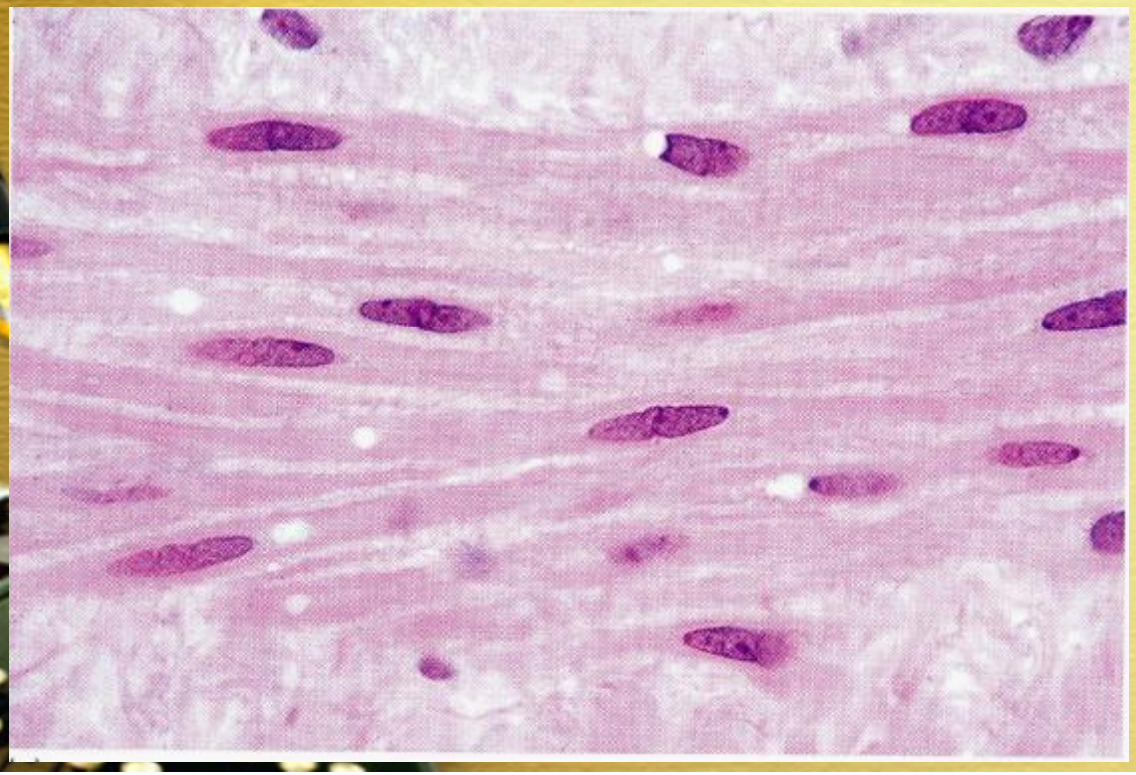


圖 12.16　參與興奮—收縮聯合的構造。從軸突末梢釋放出的乙醯膽鹼和運動終板上的菸鹼性乙醯膽鹼接受器結合，刺激去極化的產生，導致 Na^+ 通道的開啓而產生動作電位，並將訊息沿著肌漿膜傳遞到橫小管，刺激其 Ca^{2+} 通道的開啓，並以直接或間接的方式開啓肌漿質網上的 Ca^{2+} 通道。 Ca^{2+} 擴散出肌漿質網並和旋轉素結合造成肌肉的收縮。

平滑肌 (*Smooth muscle*)

1. 單一單位平滑肌：內臟平滑肌
   （胃、小腸、膀胱、子宮）
2. 多單位平滑肌：控制眼部肌肉



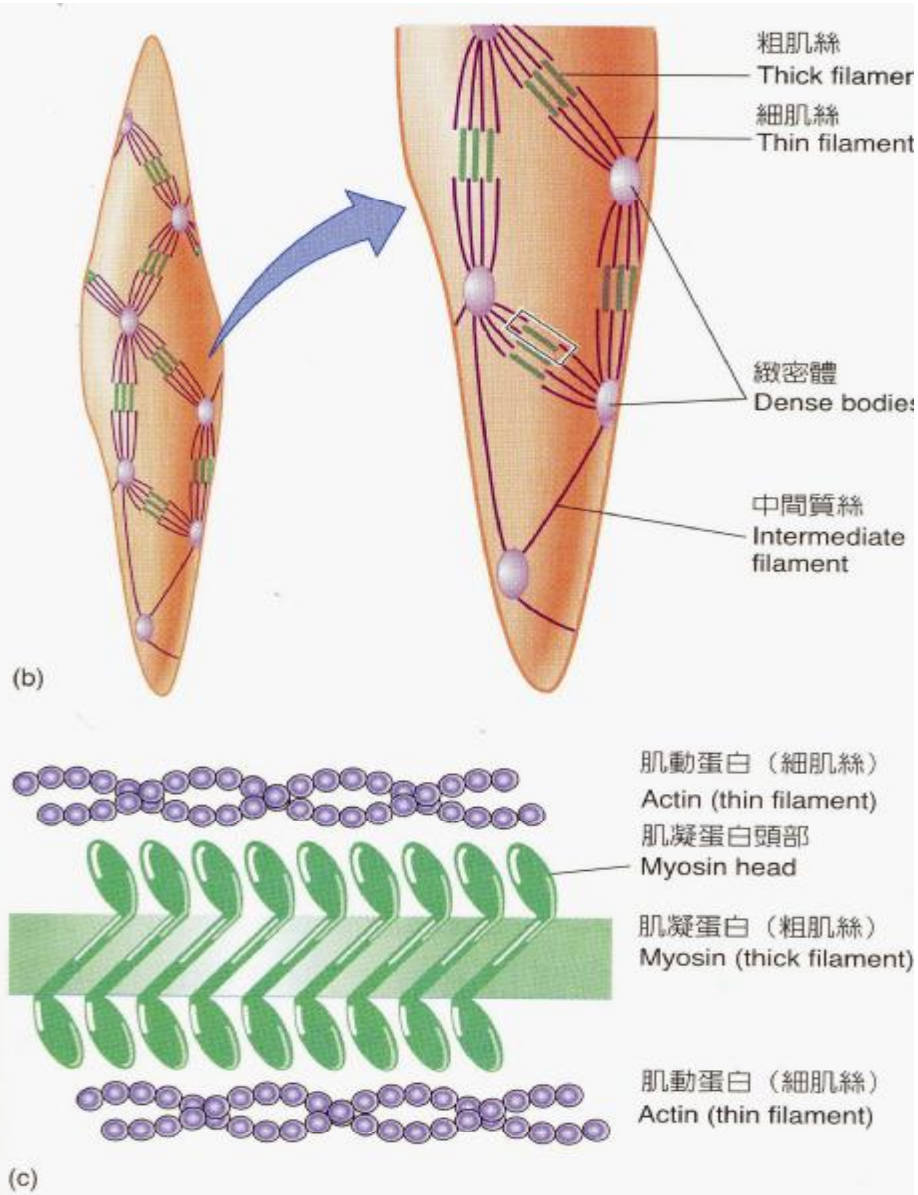


圖 12.33 平滑肌及其收縮構造。(a)血管壁平滑肌的顯微照片，(b)粗肌絲和細肌絲在平滑肌內的排列。注意緻密體之間有中間質絲相連，和(c)肌凝蛋白在平滑肌中的排列和橫紋肌不同。

圖 10.6　平滑肌的種類

(A)單一單位，或內臟平滑肌。(B)多單位之平滑肌。

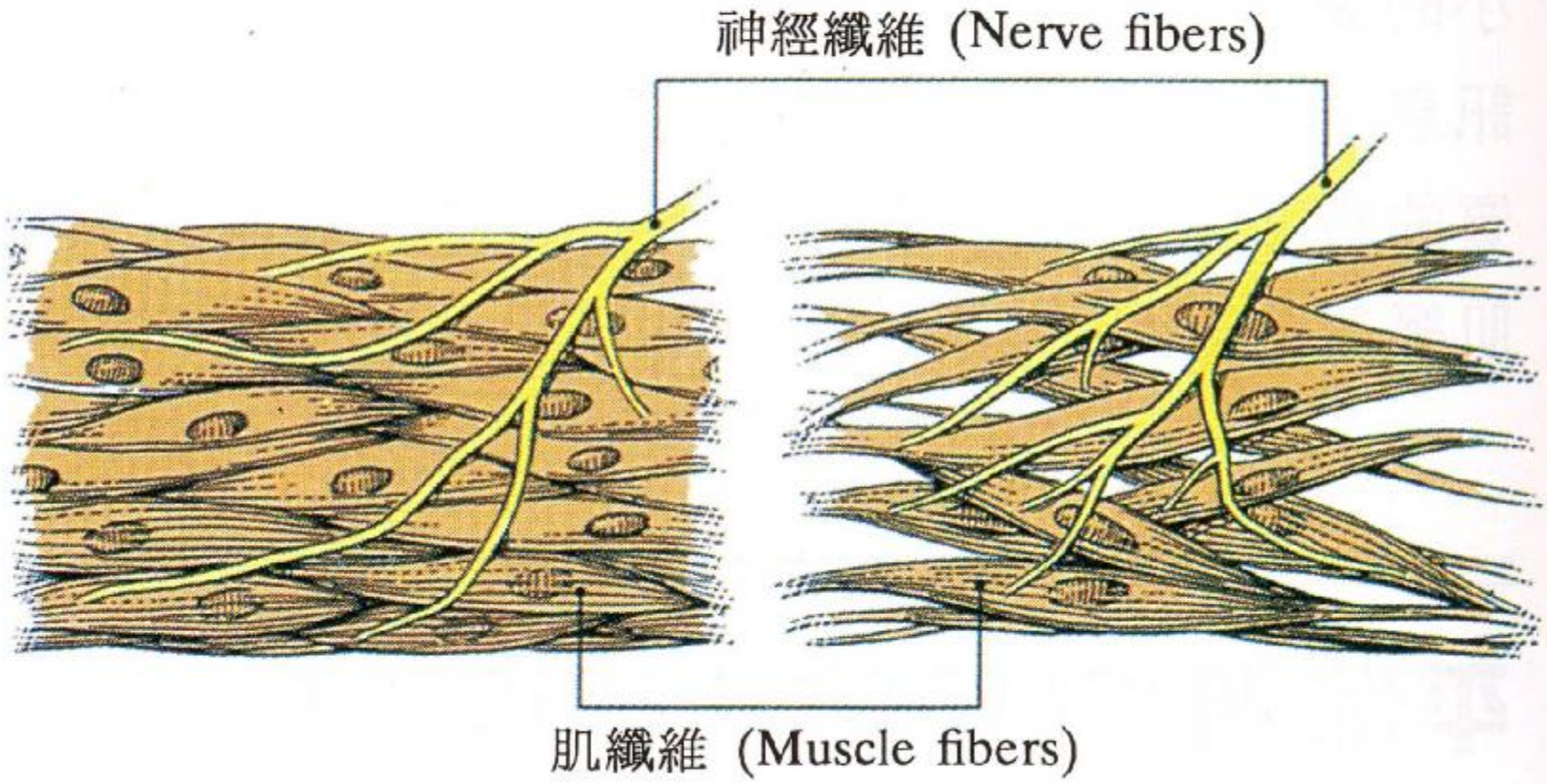
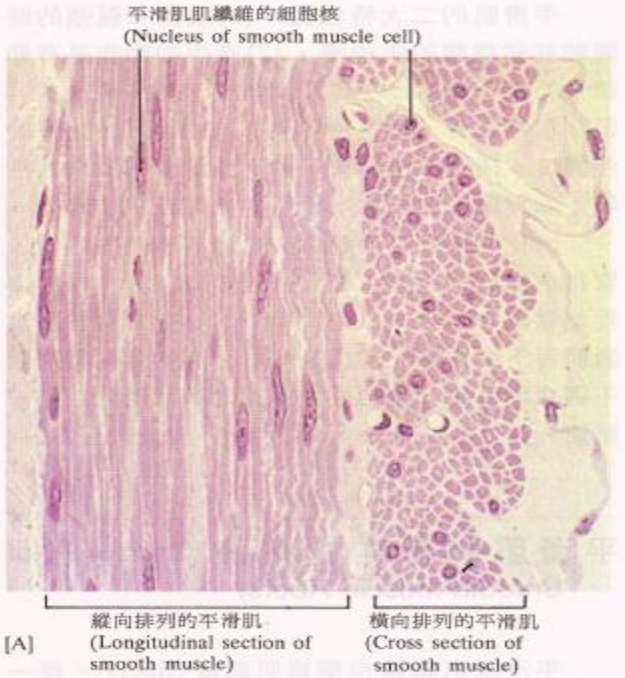
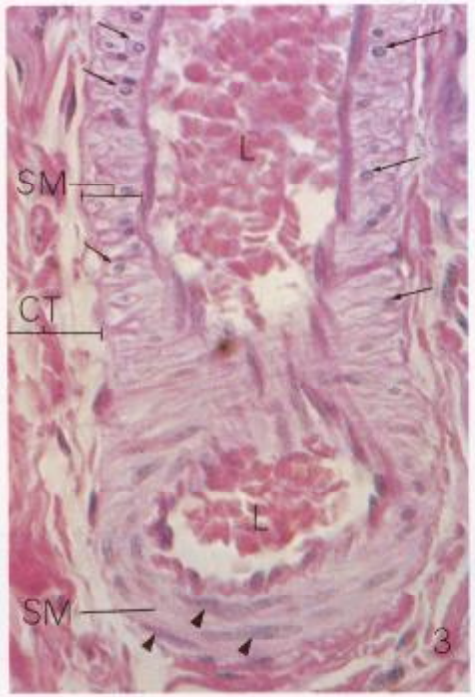
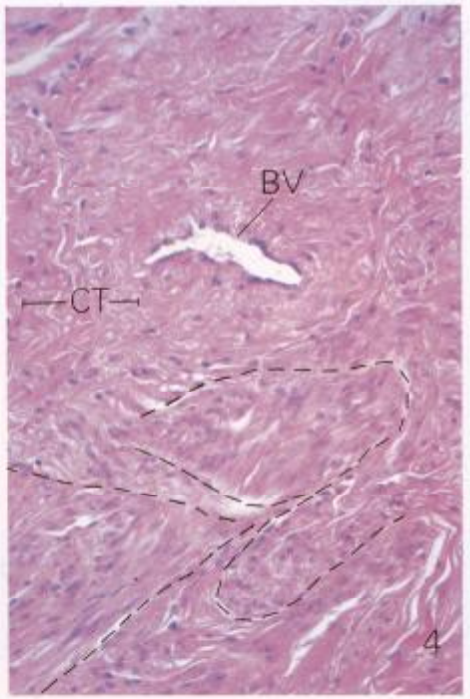


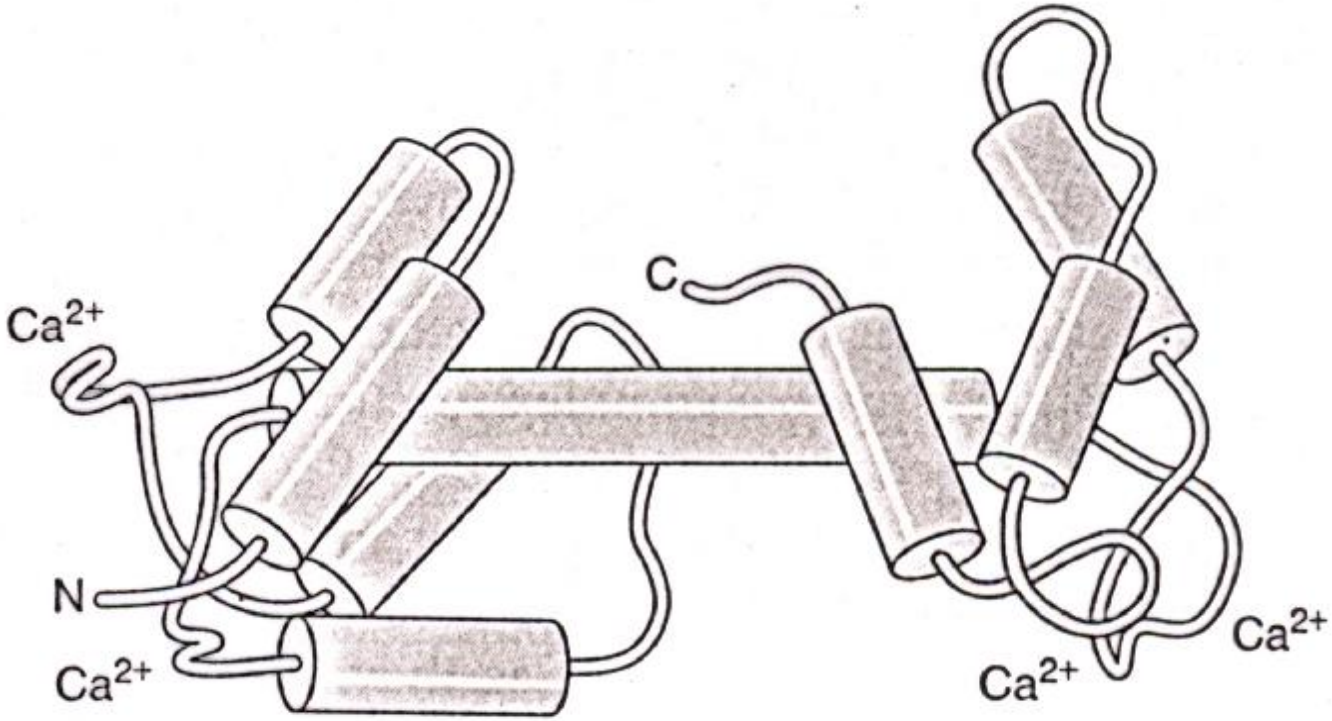
圖 10.5　平滑肌

(A)光學顯微鏡下的平滑肌組織切面圖 ×760。(B)掃瞄式電子顯微鏡下包圍靜脈的平滑肌。圖中之白色細線爲神經元之軸突， ×1000

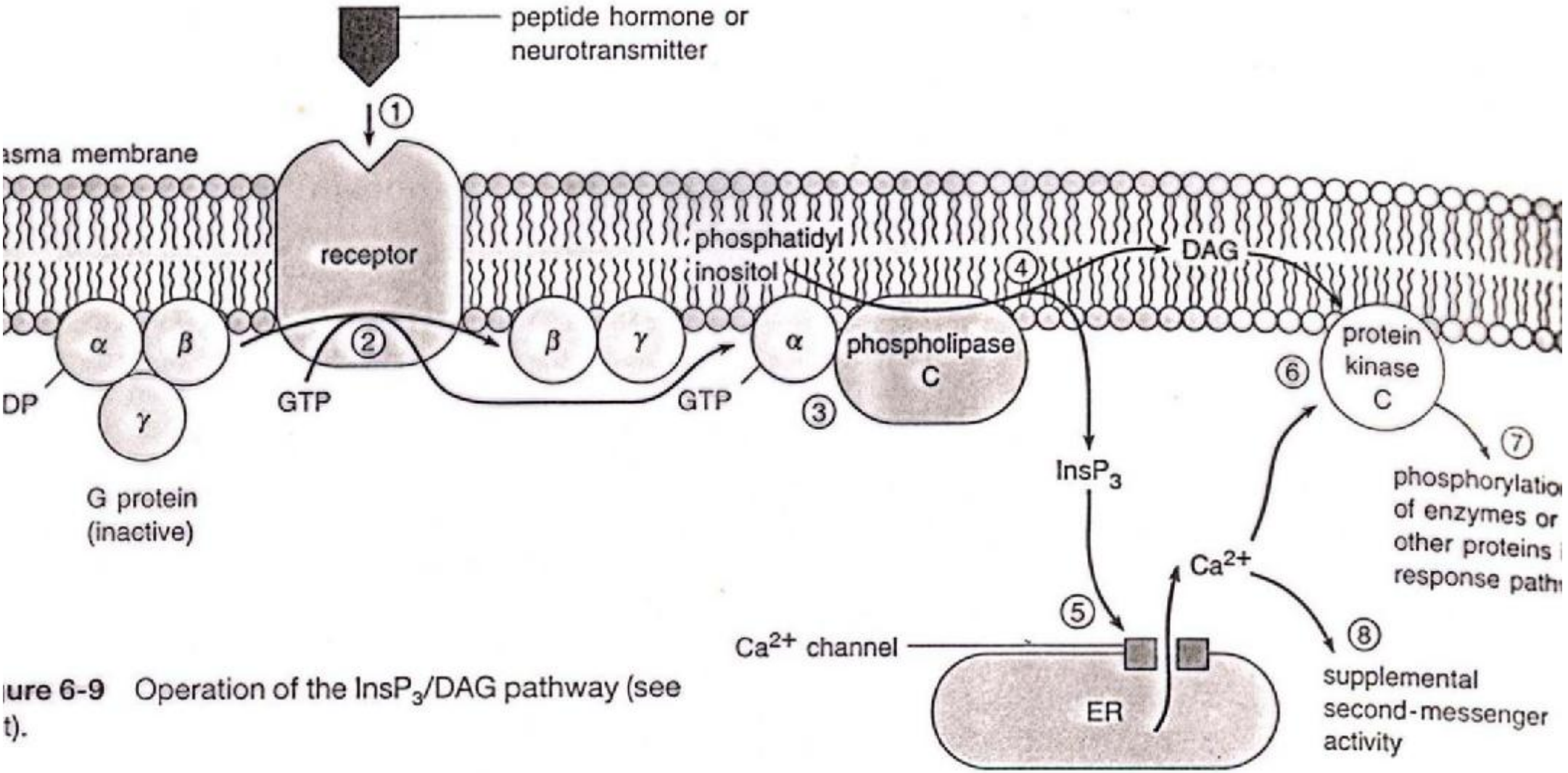








itive residues—arginine, lysine, or histidine—alternating with hydrophobic residues. This combination, which may wind into an amphipathic alpha helix, is apparently the sequence element recognized ar d bound by calmodulin. The specific amino acid sequence of the target element does not appear to be as significant for its recognition by calmodulin as its structural arrangement of alternating positive and hydrophobic residues.



ure 6-9 Operation of the $InsP_3$/DAG pathway (see
t).

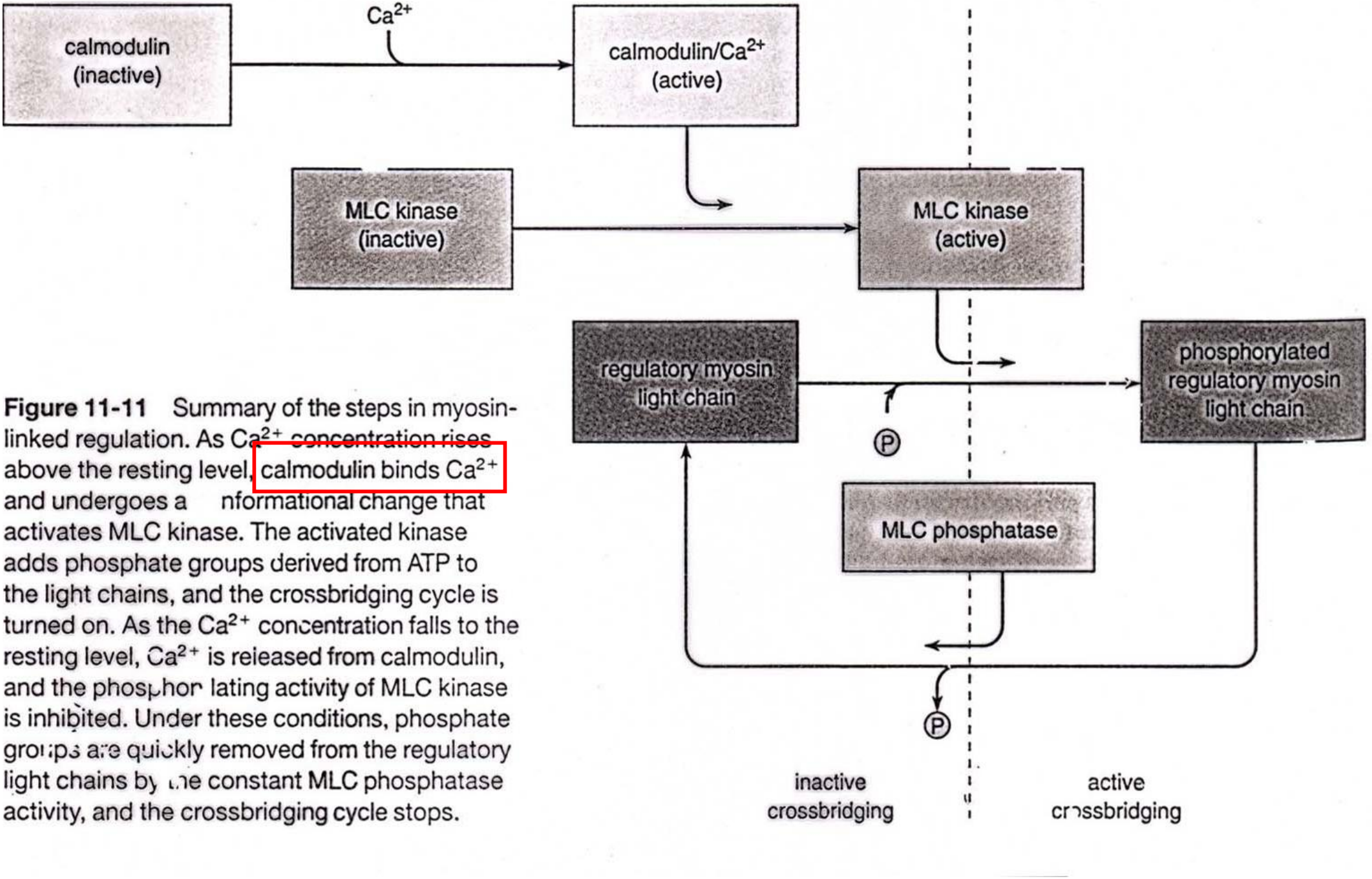


Figure 11-11 Summary of the steps in myosin-linked regulation. As Ca^{2+} concentration rises above the resting level, calmodulin binds Ca^{2+} and undergoes a conformational change that activates MLC kinase. The activated kinase adds phosphate groups derived from ATP to the light chains, and the crossbridging cycle is turned on. As the Ca^{2+} concentration falls to the resting level, Ca^{2+} is released from calmodulin, and the phosphorylating activity of MLC kinase is inhibited. Under these conditions, phosphate groups are quickly removed from the regulatory light chains by the constant MLC phosphatase activity, and the crossbridging cycle stops.

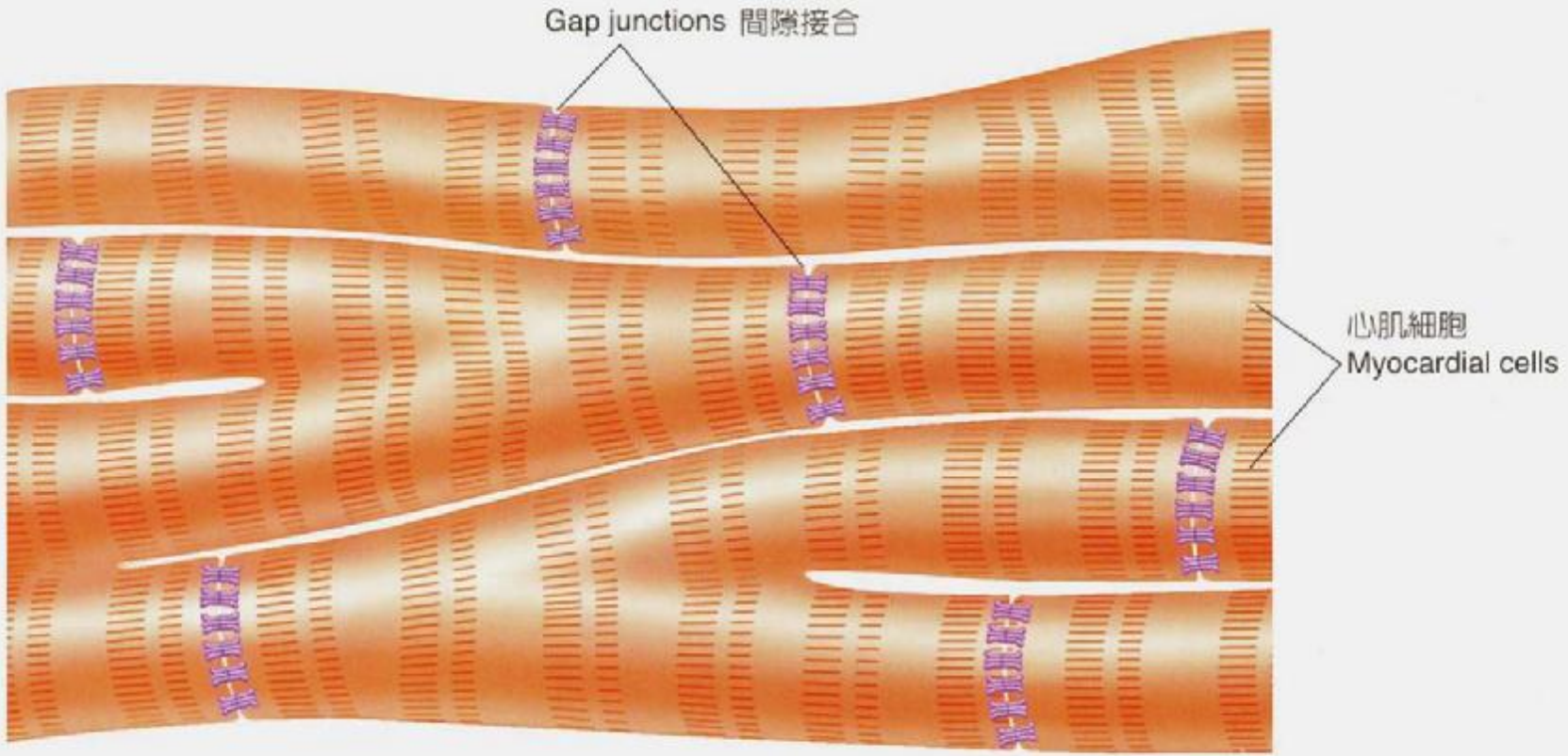


圖 12.31 **心肌細胞靠間隙接合互相聯絡**。間隙接合為內含液體的通道，所以相鄰細胞之間可以藉此傳遞電位訊號。間隙接合集中在心肌細胞末端，而每一間隙接合是由連接蛋白質組成（見第 7 章，圖 7.19）。

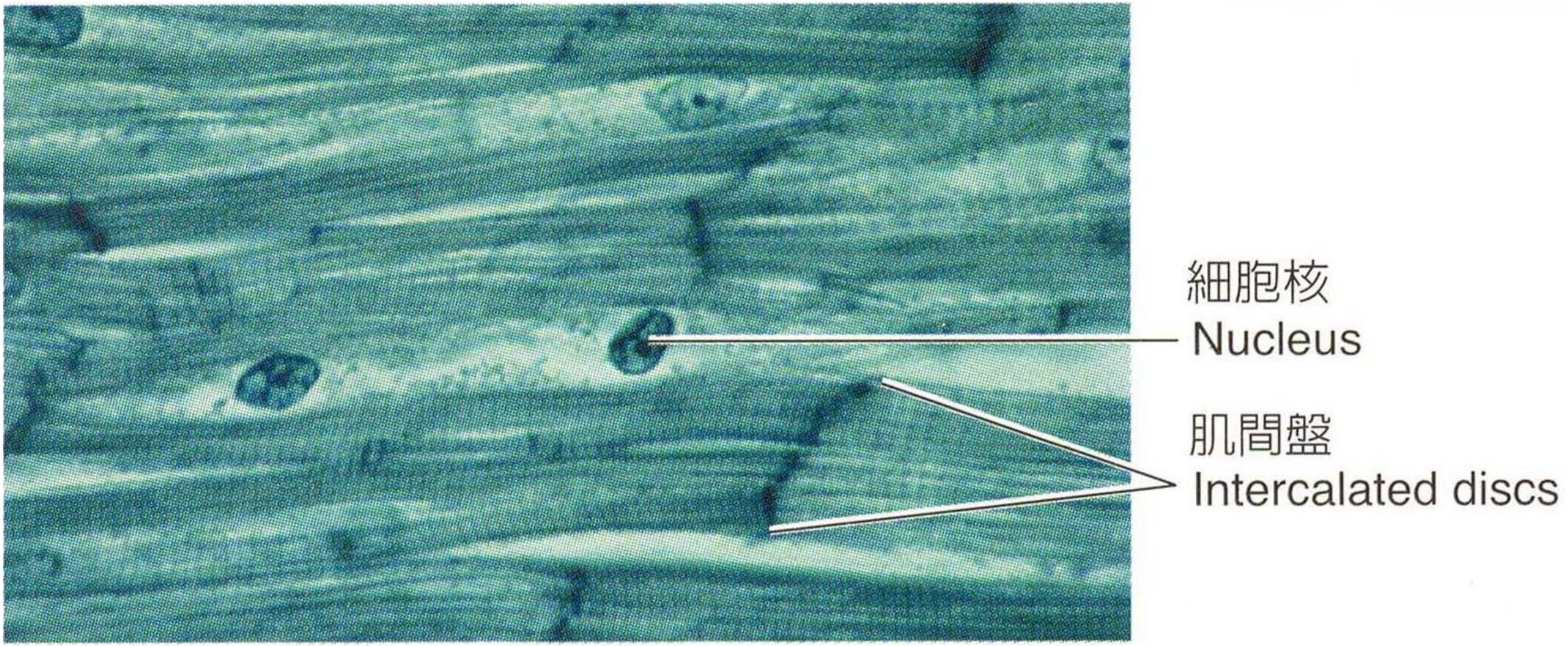
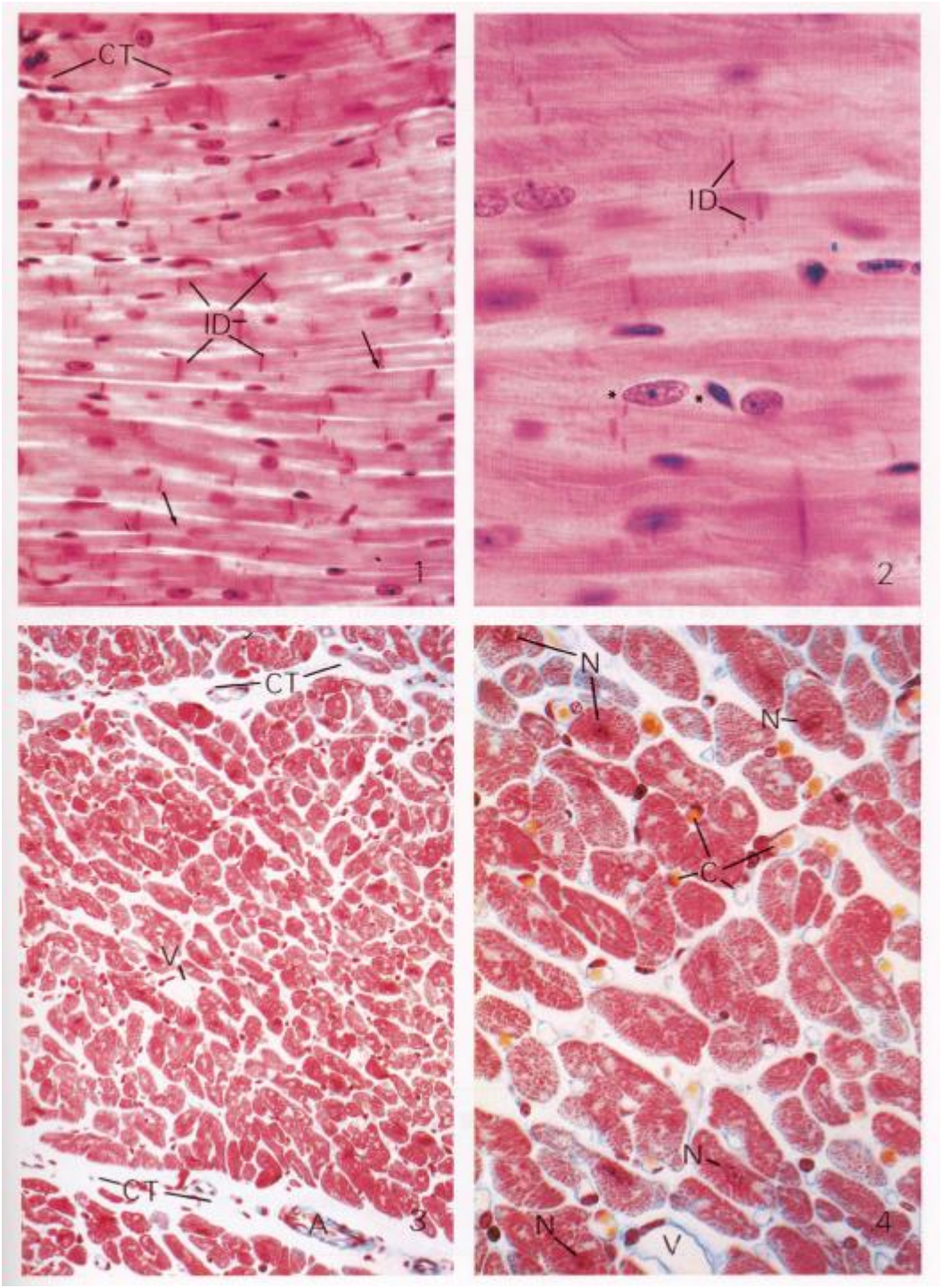


圖 12.32　心肌。注意細胞很短並具有分支和橫紋。細胞之間以肌間盤相連接。



動動你全身的肌肉，更精彩的部分才要開始！！