



KEY NOTES ON  
**PLASTIC  
SURGERY**

SECOND EDITION

**Adrian Richards**  
**Hywel Dafydd**

Foreword by Fu-Chan Wei

**WILEY** Blackwell

# Key Notes on Plastic Surgery

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## **SECOND EDITION**

FOREWORD BY PROFESSOR FU-CHAN WEI

**WILEY** Blackwell

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# Foreword

This second edition of *Key Notes on Plastic Surgery* distills the breadth and depth of the entire specialty into a compact format. Clear, concise, accurate and accessible – that is what the trainee desires when refreshing their memory of conditions during clinic, of reconstructive algorithms before operating, and of the entire syllabus when preparing for plastic surgery board examinations. *Key Notes on Plastic Surgery* fulfils this niche admirably.

A consistent balance has been struck between prose and bullet points throughout the book. *Key Notes on Plastic Surgery* fosters understanding, facilitates the commitment of information to memory, and provides structure to ease the recall of facts and principles. One can rapidly glean key information with a glance at the page and yet solidify an understanding with a few minutes' read. The textual formatting and presentation of information is where this book particularly shines.

*Key Notes on Plastic Surgery* will be embraced as a trusted companion by trainees all over the world as they progress through training and sit for their board examinations. And when they become established plastic surgeons, *Key Notes on Plastic Surgery* will take pride of place on their bookshelves as a reliable quick reference handbook for teaching the next generation.

I highly recommend *Key Notes on Plastic Surgery* to all aspiring, training and established plastic surgeons worldwide.

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# Preface

Hywel Dafydd has updated and improved the first edition of *Key Notes on Plastic Surgery*. He has worked tirelessly to include new and better diagrams and improve the content whilst maintaining the book's ethos – to succinctly communicate the essentials of Plastic Surgery.

We hope you enjoy the book and find it helpful in making you a better Plastic Surgeon.

Adrian Richards

The first edition of *Key Notes* has proved to be exceptionally popular for over a decade. Accessible, informative and succinct, it became the preferred handbook for innumerable plastic surgery trainees. It was typeset with enough 'white space' to accommodate trainees' notes and sketches as they approached their final plastic surgery examination.

Nevertheless, an update was much-needed: the field of plastic surgery has moved on apace and a detailed British plastic surgery syllabus was introduced. The material of the first edition has been updated, rewritten and expanded with several new sections to reflect this. In addition, a new chapter is provided: 'Ethics and the law'. The number of diagrams has more than doubled, which should help with learning the 'essentials', such as cleft lip repair and eyelid anatomy. *Key Notes* is now more complete and, although necessarily larger, remains true to the format and style of the first edition. We hope that *Key Notes* continues to be useful to plastic surgeons worldwide.

Hywel Dafydd

# Dedications

AR – To my Family, Helena, Josie, Ciara, Alfie and Ned.

HD – For Jenny and Ioan.

# Acknowledgements

As any Plastic Surgeon will tell you, the training and practice of the speciality takes dedication and hard work. Writing a book in your free time adds to this and requires patience and support from your family. For this reason I would like to thank my family Helena, Josie, Ciara, Alfie and Ned for their constant support. I would also like to thank my surgical mentors of whom there were many – in particular Brent Tanner and Michael Klaassen.

Adrian Richards

I would like to thank my wife Jenny and my son Ioan for their love and patience. Jenny also helped edit final drafts for brevity. Thank you Per Hall for inspiring me to become a plastic surgeon. Thanks to those who have trained me over the years in Cambridge, Wellington, Leicester, Birmingham, Coventry, Swansea, Taipei, and Auckland. Special thanks to Sarah Hemington-Gorse, Ian Josty, Dai Nguyen, Nick Wilson Jones, Tom Potokar, Peter Drew, Leong Hiew, Hamish Laing, Dean Boyce, Max Murison and Ian Pallister, who spent hours proofreading early drafts. I am also grateful to Rhidian Dafydd LLB, Karen Wong and Chris Wallace, who checked much of the text for accuracy. Tom Macleod has been a constant source of support and encouragement, and did a great deal of preparatory work on many of the chapters. The book could not have been written without the staff of Morriston Hospital's library. They sourced over 600 references from three centuries without as much as a grumble: thank you Anne, Sue, Rita and Lisa.

Hywel Dafydd

# Abbreviations

5-FU	5-fluorouracil
ABC	<i>Acinetobacter baumannii-calcoaceticus</i>
ABPI	ankle brachial pressure index
AC	alternating current
ACPA	anti-citrullinated protein antibody
ACR	American College of Rheumatology
ADH	atypical ductal hyperplasia
ADM	abductor digiti minimi
ADM	acellular dermal matrix
AER	apical ectodermal ridge
AFX	atypical fibroxanthoma
AICAP	anterior intercostal artery perforator (flap)
AIDS	acquired immune deficiency syndrome
AIN	anal intraepithelial neoplasia
AJCC	American Joint Committee on Cancer
AK	actinic keratosis
ALCL	anaplastic large T-cell lymphoma
ALH	atypical lobular hyperplasia
ALS	anti-lymphocyte serum
ALT	anterolateral thigh (flap)
ANOVA	analysis of variance
AO	<i>Arbeitsgemeinschaft für Osteosynthesefragen</i>
AP	anteroposterior
APB	abductor pollicis brevis
APC	antigen presenting cell
APL	abductor pollicis longus
APR	abdomino-perineal resection
APTT	activated partial thromboplastin time
ARDS	adult respiratory distress syndrome
ASIS	anterior superior iliac spine
ASSH	American Society for Surgery of the Hand
ATG	anti-thymoglobulin
ATLS	Advanced Trauma Life Support
AVA	arteriovenous anastomosis
AVM	arteriovenous malformation
AVN	avascular necrosis
BAAPS	British Association of Aesthetic Plastic Surgeons
BAHA	bone-anchored hearing aid



BAPRAS	British Association of Plastic, Reconstructive and Aesthetic Surgeons
BAPS	British Association of Plastic Surgeons
BCC	basal cell carcinoma
BDD	body dysmorphic disorder
BEAM	bulbar elongation and anastomotic meatoplasty
BMI	body mass index
BMP	bone morphogenetic protein
BOA	British Orthopaedic Association
BPD	biliopancreatic diversion
BRAF	B-Raf serine/threonine-protein kinase
BRBN	blue rubber bleb naevus (syndrome)
BSA	body surface area
BSSH	British Society for Surgery of the Hand
BXO	balanitis xerotica obliterans
cAMP	cyclic adenosine monophosphate
CCNE	<i>Comité Consultatif National d'Ethique</i>
CEA	cultured epithelial autograft
CFNG	cross facial nerve grafting
CI	cranial index
CIN	cervical intraepithelial neoplasia
CL	cleft lip
CM	capillary malformation
CMCJ	carpometacarpal joint
CMN	congenital melanocytic naevus
CNS	central nervous system
CO	carbon monoxide
COX	cyclooxygenase
CP	cleft palate
CPAP	continuous positive airways pressure
CPR	cardiopulmonary resuscitation
CRP	C-reactive protein
CRPS	complex regional pain syndrome
CSAG	Clinical Standards Advisory Group
CSF	cerebrospinal fluid
CT	computed tomography
CTA	composite tissue allotransplantation
CTLA	cytotoxic T-lymphocyte antigen
CTS	carpal tunnel syndrome
CVP	central venous pressure
CVS	cardiovascular system
DASH	Disabilities of the Arm, Shoulder and Hand
DBD	dermolytic bullous dermatitis
DC	direct current
DCIA	deep circumflex iliac artery

---

DCIS	ductal carcinoma <i>in situ</i>
DD	Dupuytren's disease
DEXA	dual-energy X-ray absorptiometry
DFAP	deep femoral artery perforator (flap)
DFSP	dermatofibrosarcoma protuberans
DICAP	dorsal intercostal artery perforator (flap)
DIEA	deep inferior epigastric artery
DIEP	deep inferior epigastric perforator (flap)
DIPJ	distal interphalangeal joint
DIY	do it yourself
DMARD	disease-modifying antirheumatic drug
DNA	deoxyribonucleic acid
DOPA	dihydroxyphenylalanine
DOT	double-opposing tab
DRUJ	distal radio-ulnar joint
DTH	delayed type hypersensitivity
EAST	elevated arm stress test
EBV	Epstein-Barr virus
ECG	electrocardiogram
ECRB	extensor carpi radialis brevis
ECRL	extensor carpi radialis longus
ECU	extensor carpi ulnaris
EDC	extensor digitorum communis
EDM	extensor digiti minimi
EGF	epidermal growth factor
EIP	extensor indicis proprius
ELND	elective lymph node dissection
EEMG	evoked electromyography
ELD	extended latissimus dorsi (flap)
EMG	electromyography
EMLA	eutetic mixture of local anaesthetic
ENT	ear, nose and throat
EO	external oblique
EPB	extensor pollicis brevis
EPL	extensor pollicis longus
EPUAP	European Pressure Ulcer Advisory Panel
ER	oestrogen receptor
ERK	extracellular-signal-regulated kinase
ESBL	extended-spectrum beta-lactamase
ESR	erythrocyte sedimentation rate
EULAR	European League Against Rheumatism
FAMM	facial artery musculomucosal (flap)
FAMM	familial atypical mole and melanoma (syndrome)
FBC	full blood count

FCR	flexor carpi radialis
FCU	flexor carpi ulnaris
FDA	Food and Drug Administration
FDG	fluorodeoxyglucose
FDM	flexor digiti minimi
FDMA	first dorsal metacarpal artery (flap)
FDP	flexor digitorum profundus
FDS	flexor digitorum superficialis
FFMT	free functioning muscle transfer
FFP	fresh frozen plasma
FGF	fibroblast growth factor
FGFR	fibroblast growth factor receptor
FIESTA	fast imaging employing steady-state acquisition
FISH	fluorescence <i>in situ</i> hybridisation
FLAIR	fluid attenuated inversion recovery
FNA	fine needle aspiration
FNAC	fine needle aspiration cytology
FPB	flexor pollicis brevis
FPL	flexor pollicis longus
GAG	glycosaminoglycan
GAS	group A <i>Streptococcus</i>
GCS	Glasgow coma scale
GI	gastro-intestinal
GLUT1	glucose transporter 1
GMC	General Medical Council
GP	general practitioner
Hb	haemoglobin
HER	human epidermal growth factor receptor
HES	hydroxyethyl starch
HF	hydrofluoric acid
HFS	Hannover Fracture Scale
HIT	heparin-induced thrombocytopenia
HIV	human immunodeficiency virus
HLA	human leukocyte antigen
HMB-45	human melanoma black 45
hMLH1	human mutL homolog 1 (gene)
hMSH2	human mutS homolog 2 (gene)
HPV	human papilloma virus
HRT	hormone replacement therapy
HTA	Human Tissue Authority
HU	Hounsfield units
ICAP	intercostal artery perforator (flap)
ICD	intercanthal distance
ICG	indocyanine green

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ICP	intracranial pressure
ICU	intensive care unit
IDDM	insulin dependent diabetes mellitus
IFN	interferon
IFSSH	International Federation of Societies for Surgery of the Hand
IGA	inferior gluteal artery
IGAM	inferior gluteal artery myocutaneous (flap)
IGAP	inferior gluteal artery perforator (flap)
IHC	immunohistochemistry
IJV	internal jugular vein
IL	interleukin
IMF	inframammary fold
IMF	intermaxillary fixation
IMNAS	Institute of Medicine of the National Academy of Science
INR	international normalised ratio
IO	internal oblique
IOD	interorbital distance
IPJ	interphalangeal joint
IPL	intense pulsed light
IRG	Independent Review Group
ISSVA	International Society for the Study of Vascular Anomalies
ITL	inferior temporal line
ITU	intensive therapy unit
IV	intravenous
IVF	<i>in vitro</i> fertilisation
KA	keratoacanthoma
KTP	potassium titanyl phosphate
KTS	Klippel-Trénaunay syndrome
LA	local anaesthesia
LASER	light amplification by stimulated emission of radiation
LCIS	lobular carcinoma <i>in situ</i>
LD	latissimus dorsi
LDH	lactate dehydrogenase
LDMF	latissimus dorsi miniflap
LEAP	Lower Extremity Assessment Project
LHRH	lutinising hormone releasing hormone
LICAP	lateral intercostal artery perforator (flap)
LISN	lobular <i>in situ</i> neoplasia
LM	lentigo maligna
LM	lymphatic malformation
LME	line of maximum extensibility
LMM	lentigo maligna melanoma
LMWH	low-molecular-weight heparin
LRTI	ligament reconstruction and tendon interposition

LSI	Limb Salvage Index
LSMDT	local skin cancer multidisciplinary team
MACS	Minimal Access Cranial Suspension
MAGPI	meatal advancement and glanuloplasty incorporated
MAL	methyl aminolevulinate
MAPK	mitogen-activated protein kinase
MARIA	Multistatic Array Processing for Radiowave Image Acquisition
MART	melanoma antigen recognised by T cells
MCA	Mental Capacity Act
MCC	Merkel cell carcinoma
MCPJ	metacarpophalangeal joint
MDT	multidisciplinary team
MEK	mitogen/extracellular signal-regulated kinase
MESS	Mangled Extremity Severity Score
MFH	malignant fibrous histiocytoma
MHC	major histocompatibility complex
MHRA	Medicines and Healthcare Products Regulatory Agency
MIP	megameatus intact prepuce
MLD	manual lymphatic drainage
MM	malignant melanoma
MMF	mandibulomaxillary fixation
MODS	multiple organ dysfunction syndrome
MPNST	malignant peripheral nerve sheath tumour
MRC	Medical Research Council
MRI	magnetic resonance imaging
MRKH	Mayer–Rokitansky–Küster–Hauser (syndrome)
MRND	modified radical neck dissection
MRSA	methicillin resistant <i>Staphylococcus aureus</i>
MS	muscle sparing
MSG	Melanoma Study Group
MSH	melanocyte-stimulating hormone
MSLT	Multicenter Selective Lymphadenectomy Trial
MSU	monosodium urate
MSX2	msh homeobox 2 (gene)
mTOR	mammalian target of rapamycin
MTPJ	metatarsophalangeal joint
MTT	malignant triton tumour
NAC	nipple-areola complex
NAI	non-accidental injury
NASHA	non-animal stabilised hyaluronic acid
NCS	nerve conduction studies
NF	neurofibromatosis
NG	nasogastric
NHS	National Health Service

---

NICH	noninvoluting congenital haemangioma
NK	natural killer (cell)
NOE	nasoorbitoethmoidal
NPA	nasopharyngeal airway
NPI	Nottingham Prognostic Index
NPUAP	National Pressure Ulcer Advisory Panel
NPWT	negative pressure wound therapy
NSAID	non-steroidal anti-inflammatory drug
NSM	nipple sparing mastectomy
NVB	neurovascular bundle
OA	osteoarthritis
OGS	orthognathic surgery
OM	osteomyelitis
OP	opponens pollicis
ORIF	open reduction and internal fixation
PA	posteroanterior
PAL	power-assisted liposuction
PABA	para-amino benzoic acid
PAF	platelet activating factor
PCNA	proliferating cell nuclear antigen (gene)
PDE	phosphodiesterase
PDE	Photodynamic Eye
PDGF	platelet-derived growth factor
PDS	polydioxanone sulphate
PDT	photodynamic therapy
PEEP	positive end-expiratory pressure
PET	polyethylene terephthalate
PET	positron emission tomography
PHA	progressive hemifacial atrophy
PIN	posterior interosseous nerve
PIP	Poly Implant Prothèse
PIPJ	proximal interphalangeal joint
PL	palmaris longus
PL	phospholipid
PMMA	polymethylmethacrylate
PMN	polymorphonuclear neutrophils
POSI	position of safe immobilisation
PR	progesterone receptor
PRPC	platelet-rich plasma concentrate
PRS	Pierre Robin sequence
PSI	Predictive Salvage Index
PSIS	posterior superior iliac spine
PT	prothrombin time
PT	pronator teres

PTCH	patched (gene)
PTEN	phosphatase and tensin homolog (gene)
PTFE	polytetrafluoroethylene
RA	rectus abdominis
RA	rheumatoid arthritis
RAPD	relative afferent pupillary defect
RCT	randomised controlled trial
REE	resting energy expenditure
RF	rheumatoid factor
RFAL	radiofrequency assisted liposuction
RFF	radial forearm flap
RICH	rapidly involuting congenital haemangioma
RND	radical neck dissection
ROOF	retro-orbicularis oculi fat (pad)
RSTL	relaxed skin tension line
SAL	suction-assisted liposuction
SAN	spinal accessory nerve
SCAP	syringocystadenoma papilliferum
SCC	squamous cell carcinoma
SCIA	superficial circumflex iliac artery
SCM	sternocleidomastoid
SEPS	subfascial endoscopic perforating vein surgery
SFS	superficial fascial system
SGAP	superior gluteal artery perforator (flap)
SHH	sonic hedgehog
SIEA	superficial inferior epigastric artery (flap)
SIRS	systemic inflammatory response syndrome
SJS	Stevens-Johnson syndrome
SLE	systemic lupus erythematosus
SLL	scapholunate ligament
SLNB	sentinel lymph node biopsy
SMAS	superficial muscular aponeurotic system
SNAP	sensory nerve action potential
SNAP	synaptosomal-associated protein
SND	selective neck dissection
SNUC	sinonasal undifferentiated carcinoma
SOOF	suborbicularis oculi fat (pad)
SPAIR	short scar periareolar inferior pedicle reduction
SRY	sex-determining region of the Y chromosome
SSD	silver sulfadiazine
SSM	skin sparing mastectomy
SSSS	staphylococcal scalded skin syndrome
STIR	short T1 inversion recovery
STL	superior temporal line

---

STS	soft tissue sarcoma
STT	scaphotrapezium-trapezoid
TA	transversus abdominis
TAM	total active motion
TAR	thrombocytopenia – absent radius (syndrome)
TB	tubercle bacillus
TBSA	total body surface area
TCA	trichloroacetic acid
TDA	toluene diamine
TDAP	thoracodorsal artery perforator
TED	thromboembolic device
TEN	toxic epidermal necrolysis
TF	tissue factor
TFL	tensor fasciae latae
TGF	transforming growth factor
TIMP	tissue inhibitor of metalloproteinase
TIP	tubularised incised plate
TMJ	temporomandibular joint
TNF	tumour necrosis factor
TNM	tumour, nodes, metastasis
TNMG	tumour, nodes, metastasis, grade
TOS	thoracic outlet syndrome
t-PA	tissue plasminogen activator
TPN	total parenteral nutrition
TRAM	transverse rectus abdominis myocutaneous (flap)
TRT	thermal relaxation time
TSS	toxic shock syndrome
TSST	toxic shock syndrome toxin
TUG	transverse upper gracilis
TWIST	twist family basic helix-loop-helix transcription factor (gene)
UAL	ultrasound-assisted liposuction
UCL	ulnar collateral ligament
UK	United Kingdom
USA	United States of America
USP	United States Pharmacopeia
UV	ultraviolet
USS	ultrasound scan
VAIN	vaginal intraepithelial neoplasia
VASER	Vibration Amplification of Sound Energy at Resonance
VCA	vascularised composite allotransplantation
VEGF	vascular endothelial growth factor
VEGFR	vascular endothelial growth factor receptor
VF	ventricular fibrillation
VIN	vulval intraepithelial neoplasia



VM	venous malformation
VMCM	multiple cutaneous and mucosal venous malformations
VPI	velopharyngeal insufficiency
VRAM	vertical rectus abdominis myocutaneous (flap)
VRE	vancomycin resistant <i>Enterococcus</i>
vWF	von Willebrand factor
WHO	World Health Organisation
WLE	wide local excision
WNT7A	wingless-type MMTV integration site family, member 7A
XP	xeroderma pigmentosa
YAG	yttrium aluminium garnet
ZF	zygomaticofrontal
ZM	zygomaticomaxillary
ZPA	zone of polarising activity

# CHAPTER 1

## General Principles

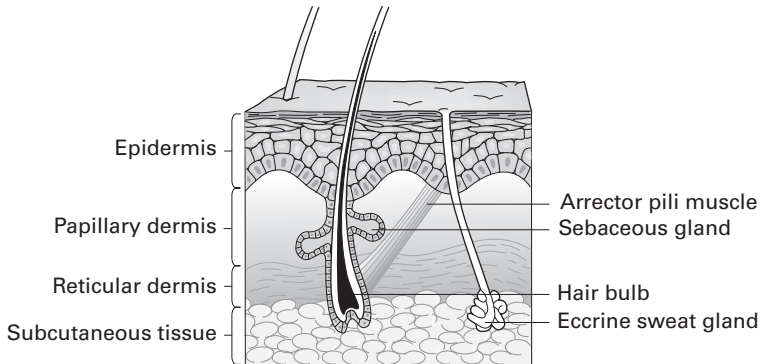
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### Embryology, structure and function of the skin

- Skin differentiates from ectoderm and mesoderm during the 4th week.
- Skin gives rise to:
  - Teeth and hair follicles, derived from epidermis and dermis
  - Fingernails and toenails, derived from epidermis only.
- Hair follicles, sebaceous glands, sweat glands, apocrine glands and mammary glands are 'epidermal appendages' because they develop as ingrowths of epidermis into dermis.
- Functions of skin:
  - 1 Physical protection
  - 2 Protection against UV light
  - 3 Protection against microbiological invasion
  - 4 Prevention of fluid loss

- 5 Regulation of body temperature
- 6 Sensation
- 7 Immunological surveillance.



## The epidermis

- Composed of stratified squamous epithelium.
- Derived from ectoderm.
- Epidermal cells undergo keratinisation – their cytoplasm is replaced with keratin as the cell dies and becomes more superficial.
- Rete ridges are epidermal thickenings that extend downward between dermal papillae.
- Epidermis is composed of these five layers, from deep to superficial:

### 1 Stratum germinativum

- Also known as the basal layer.
- Cells within this layer have cytoplasmic projections (hemidesmosomes), which firmly link them to the underlying basal lamina.
- The only actively proliferating layer of skin.
- Stratum germinativum also contains melanocytes.

### 2 Stratum spinosum

- Also known as the prickle cell layer.
- Contains large keratinocytes, which synthesise cytokeratin.
- Cytokeratin accumulates in aggregates called tonofibrils.
- Bundles of tonofibrils converge into numerous desmosomes (prickles), forming strong intercellular contacts.

### 3 Stratum granulosum

- Contains mature keratinocytes, with cytoplasmic granules of keratohyalin.
- The predominant site of protein synthesis.
- Combination of cytokeratin tonofibrils with keratohyalin produces keratin.

### 4 Stratum lucidum

- A clear layer, only present in the thick glabrous skin of palms and feet.

## 5 Stratum corneum

- Contains non-viable keratinised cells, having lost their nuclei and cytoplasm.
- Protects against trauma.
- Insulates against fluid loss.
- Protects against bacterial invasion and mechanical stress.

## Cellular composition of the epidermis

- Keratinocytes – the predominant cell type in the epidermis.
- Langerhans cells – antigen-presenting cells (APCs) of the immune system.
- Merkel cells – mechanoreceptors of neural crest origin.
- Melanocytes – neural crest derivatives:
  - Usually located in the stratum germinativum.
  - Produce melanin packaged in melanosomes, which is delivered along dendrites to surrounding keratinocytes.
  - Melanosomes form a cap over the nucleus of keratinocytes, protecting DNA from UV light.

## The dermis

- Accounts for 95% of the skin's thickness.
- Derived from mesoderm.
- Papillary dermis is superficial; contains more cells and finer collagen fibres.
- Reticular dermis is deeper; contains fewer cells and coarser collagen fibres.
- It sustains and supports the epidermis.
- Dermis is composed of:

### 1 Collagen fibres

- Produced by fibroblasts.
- Through cross-linking, are responsible for much of the skin's strength.
- The normal ratio of type 1 to type 3 collagen is 5:1.

### 2 Elastin fibres

- Secreted by fibroblasts.
- Responsible for elastic recoil of skin.

### 3 Ground substance

- Consists of glycosaminoglycans (GAGs): hyaluronic acid, dermatan sulphate, chondroitin sulphate.
- GAGs are secreted by fibroblasts and become ground substance when hydrated.

### 4 Vascular plexus

- Separates the denser reticular dermis from the overlying papillary dermis.

## Skin appendages

### Hair follicles

- Each hair is composed of a medulla, a cortex and an outer cuticle.
- Hair follicles consist of an inner root sheath (derived from epidermis), and an outer root sheath (derived from dermis).

- Several sebaceous glands drain into each follicle.
  - Drainage of the glands is aided by contraction of arrector pili muscles.
- Vellus hairs are fine and downy; terminal hairs are coarse.
- Hairs are either in anagen (growth), catagen (regressing), or telogen (resting) phase.
  - <90% are in anagen, 1–2% in catagen and 10–14% in telogen at any one time.

### **Eccrine glands**

- These sweat glands secrete odourless hypotonic fluid.
- Present in almost all sites of the body.
- Occur more frequently in the palm, sole and axilla.

### **Apocrine glands**

- Located in axilla and groin.
- Emit a thicker secretion than eccrine glands.
- Responsible for body odour; do not function before puberty.
- Modified apocrine glands are found in the external ear (ceruminous glands) and eyelid (Moll glands).
- The mammary gland is a modified apocrine gland specialised for manufacture of colostrum and milk.
- Hidradenitis suppurativa is a disease of apocrine glands.

### **Sebaceous glands**

- Holocrine glands that drain into the pilosebaceous unit in hair-bearing skin.
- They drain directly onto skin in the labia minora, penis and tarsus (meibomian glands).
- Most prevalent on forehead, nose and cheek; absent from palms and soles.
- Produce sebum, which contains fats and their breakdown products, wax esters and debris of dead fat-producing cells.
  - Sebum is bactericidal to staphylococci and streptococci.
- Sebaceous glands are not the sole cause of so-called sebaceous cysts.
- These cysts are in fact of epidermal origin and contain all substances secreted by skin (predominantly keratin).
  - Some maintain they should therefore be called epidermoid cysts.

### **Types of secretion from glands**

- Eccrine or merocrine glands secrete opened vesicles via exocytosis.
- Apocrine glands secrete by 'membrane budding' – pinching off part of the cytoplasm in vesicles bound by the cell's own plasma membrane.
- Holocrine gland secretions are produced within the cell, followed by rupture of the cell's plasma membrane.

### **Histological terms**

- Acanthosis: epidermal hyperplasia.
- Papillomatosis: increased depth of corrugations at the dermoepidermal junction.
- Hyperkeratosis: increased thickness of the keratin layer.

- Parakeratosis: presence of nucleated cells at the skin surface.
- Pagetoid: when cells invade the upper epidermis from below.
- Palisading: when cells are oriented perpendicular to a surface.

## Blood supply to the skin

- Epidermis contains no blood vessels.
- It is dependent on dermis for nutrients, supplied by diffusion.

## Anatomy of the circulation

- Blood reaching the skin originates from named deep vessels.
- These feed interconnecting vessels, which supply the vascular plexuses of fascia, subcutaneous tissue and skin.

## Deep vessels

- Arise from the aorta and divide to form the main arterial supply to head, neck, trunk and limbs.

## Interconnecting vessels

- The interconnecting system is composed of:
  - Fasciocutaneous (or septocutaneous) vessels
    - Reach the skin *directly* by traversing fascial septa.
    - Provide the main arterial supply to skin in the limbs.
- Musculocutaneous vessels
  - Reach the skin *indirectly* via muscular branches from the deep system.
  - These branches enter muscle bellies and divide into multiple perforating branches, which travel up to the skin.
  - Provide the main arterial supply to skin of the torso.

## Vascular plexuses of fascia, subcutaneous tissue and skin

- 1 Subfascial plexus
  - Small plexus lying on the undersurface of deep fascia.
- 2 Prefascial plexus
  - Larger plexus superficial to deep fascia; prominent on the limbs.
  - Predominantly supplied by fasciocutaneous vessels.
- 3 Subcutaneous plexus
  - At the level of superficial fascia.
  - Mainly supplied by musculocutaneous vessels.
  - Predominant on the torso.
- 4 Subdermal plexus
  - Receives blood from the underlying plexuses.
  - The main plexus supplying blood to skin.
  - Accounts for dermal bleeding observed in incised skin.

5 Dermal plexus

- Mainly composed of arterioles.
- Plays an important role in thermoregulation.

6 Subepidermal plexus

- Contains small vessels without muscle in their walls.
- Predominantly nutritive and thermoregulatory function.

**Angiosomes**

- An angiosome is a three-dimensional composite block of tissue supplied by a named artery.
- The area of skin supplied by an artery was first studied by Manchot in 1889.
- His work was expanded by Salmon in the 1930s, and more recently by Taylor and Palmer.
- The anatomical territory of an artery is the area into which the vessel ramifies before anastomosing with adjacent vessels.
- The dynamic territory of an artery is the area into which staining extends after intravascular infusion of fluorescein.
- The potential territory of an artery is the area that can be included in a flap if it is delayed.
- Vessels that pass between anatomical territories are called choke vessels.
- The transverse rectus abdominis myocutaneous (TRAM) flap illustrates the angiosome concept well:

**Zone 1**

- Receives musculocutaneous perforators from the deep inferior epigastric artery (DIEA) and is therefore in its anatomical territory.

**Zones 2 and 3**

- There is controversy as to which of the following zones is 2 and which is 3.
- Hartrampf's 1982 description has zone 2 across the midline and zone 3 lateral to zone 1.
  - Holm's 2006 study shows the opposite to be true.
- Skin lateral to zone 1 is in the anatomical territory of the superficial circumflex iliac artery (SCIA).
  - Blood has to travel through a set of choke vessels to reach it from the ipsilateral DIEA.
- Skin on the contralateral side of the linea alba is in the anatomical area of the ipsilateral DIEA.
  - It is also within the dynamic territory of the contralateral DIEA.
  - This allows a TRAM flap to be reliably perfused based on either DIEA.

**Zone 4**

- This lies furthest from the pedicle and is in the anatomical territory of the contralateral SCIA.
- Blood passing from the pedicle to zone 4 has to cross two sets of choke vessels.
- This portion of the TRAM flap has the worst blood supply and is often discarded.

**Arterial characteristics**

- Taylor made the following observations from his detailed anatomical dissections:
  - Vessels usually travel with nerves.
  - Vessels obey the law of equilibrium – if one is small, its neighbour will tend to be large.

- Vessels travel from fixed to mobile tissue.
- Vessels have a fixed destination but varied origin.
- Vessel size and orientation is a product of growth.

### **Venous characteristics**

- Venous networks consist of linked valvular and avalvular channels that allow equilibrium of flow and pressure.
- Directional veins are valved; typically found in subcutaneous tissues of limbs or as a stellate pattern of collecting veins.
- Oscillating avalvular veins allow free flow between valved channels of adjacent venous territories.
  - They mirror and accompany choke arteries.
  - They define the perimeter of venous territories in the same way choke arteries define arterial territories.
- Superficial veins follow nerves; perforating veins follow perforating arteries.

### **The microcirculation**

- Terminal arterioles are found in reticular dermis.
  - They terminate as they enter the capillary network.
- The precapillary sphincter is the last part of the arterial tree containing muscle within its wall.
  - It is under neural control and regulates blood flow into the capillary network.
- The skin's blood supply far exceeds its nutritive requirements.
- It bypasses capillary beds via arteriovenous anastomoses (AVAs) and has a primarily thermoregulatory function.
  - AVAs connect arterioles to efferent veins.
- AVAs are of two types:
  - 1 Indirect AVAs – convoluted structures known as glomera (*sing.* glomus)
    - Densely innervated by autonomic nerves.
  - 2 Direct AVAs – less convoluted with sparser autonomic supply.

### **Control of blood flow**

- The muscular tone of vessels is controlled by:

### **Pressure of the blood within vessels (myogenic theory)**

- Originally described by Bayliss, states that:
  - Increased intraluminal pressure results in constriction of vessels.
  - Decreased intraluminal pressure results in their dilatation.
- Helps keep blood flow constant; accounts for hyperaemia on release of a tourniquet.

### **Neural innervation**

- Arterioles, AVAs and precapillary sphincters are sympathetically innervated.
- Increased arteriolar tone results in decreased cutaneous blood flow.
- Increased precapillary sphincter tone reduces blood flow into capillary networks.
- Decreased AVA tone increases non-nutritive blood flow bypassing the capillary bed.



### **Humoral factors**

- Epinephrine, norepinephrine, serotonin, thromboxane A<sub>2</sub> and prostaglandin F<sub>2α</sub> cause vasoconstriction.
- Histamine, bradykinin and prostaglandin E<sub>1</sub> cause vasodilatation.
- Low O<sub>2</sub> saturation, high CO<sub>2</sub> saturation and acidosis also cause vasodilatation.

### **Temperature**

- Heat causes cutaneous vasodilatation and increased flow, which predominantly bypasses capillary beds via AVAs.

### **The delay phenomenon**

- Delay is any preoperative manoeuvre that results in increased flap survival.
- Historical examples include Tagliacozzi's nasal reconstruction described in the 16th century.
  - Involves elevation of a bipediced flap with length : breadth ratio of 2:1.
  - The flap can be considered as two 1:1 flaps.
  - Cotton lint is placed under the flap, preventing its reattachment.
  - Two weeks later, one end of the flap is detached from the arm and attached to the nose.
    - A flap of these dimensions transferred without a delay procedure would have a significant chance of distal necrosis.
- Delay is occasionally used for pedicled TRAM breast reconstruction.
  - The DIEA is ligated two weeks prior to flap transfer.
- The mechanism of delay remains incompletely understood.
- These theories have been proposed to explain the delay phenomenon:

### **Increased axially of blood flow**

- Removal of blood flow from the periphery of a random flap promotes development of an axial blood supply from its base.
- Axial flaps have improved survival compared to random flaps.

### **Tolerance to ischaemia**

- Cells become accustomed to hypoxia after the initial delay procedure.
- Less tissue necrosis therefore occurs after the second operation.

### **Sympathectomy vasodilatation theory**

- Dividing sympathetic fibres at the borders of a flap results in vasodilatation and improved blood supply.
- But why, if sympathectomy is immediate, does the delay phenomenon only begin to appear at 48 hours, and why does it take 2 weeks for maximum effect?

### **Intraflap shunting hypothesis**

- Postulates that sympathectomy dilates AVAs, resulting in an increase in nonnutritive blood flow bypassing the capillary bed.
- A greater length of flap will survive at the second stage as there are fewer sympathetic fibres to cut and therefore less of a reduction in nutritive blood flow.

### Hyperadrenergic state

- Surgery results in increased tissue concentrations of vasoconstrictors, such as epinephrine and norepinephrine.
- After the initial delay procedure, the resultant reduction in blood supply is not sufficient to produce tissue necrosis.
  - The level of vasoconstrictor substances returns to normal before the second procedure.
- The second procedure produces another rise in the concentration of vasoconstrictor substances.
  - This rise is said to be smaller than it would be if the flap were elevated without a prior delay.
- The flap is therefore less likely to undergo distal necrosis after a delay procedure.

### Unifying theory

- Described by Pearl in 1981; incorporates elements of all these theories.

## Classification of flaps

- Flaps can be classified by the five 'C's':
  - Circulation
  - Composition
  - Contiguity
  - Contour
  - Conditioning.

### Circulation

- Can be further subcategorised into:
  - Random
  - Axial (direct, fasciocutaneous, musculocutaneous, or venous).

### Random flaps

- No directional blood supply; not based on a named vessel.
- These include most local flaps on the face.
- Should have a maximum length: breadth ratio of 1:1 in the lower extremity, as it has a relatively poor blood supply.
  - Can be up to 6:1 in the face, as it has a good blood supply.

### Axial flaps

#### Direct

- Contain a named artery running in subcutaneous tissue along the axis of the flap.
- Examples include:
  - Groin flap, based on superficial circumflex iliac vessels.
  - Deltopectoral flap, based on perforating vessels of internal mammary artery.
- Both flaps can include a random segment in their distal portions after the artery peters out.