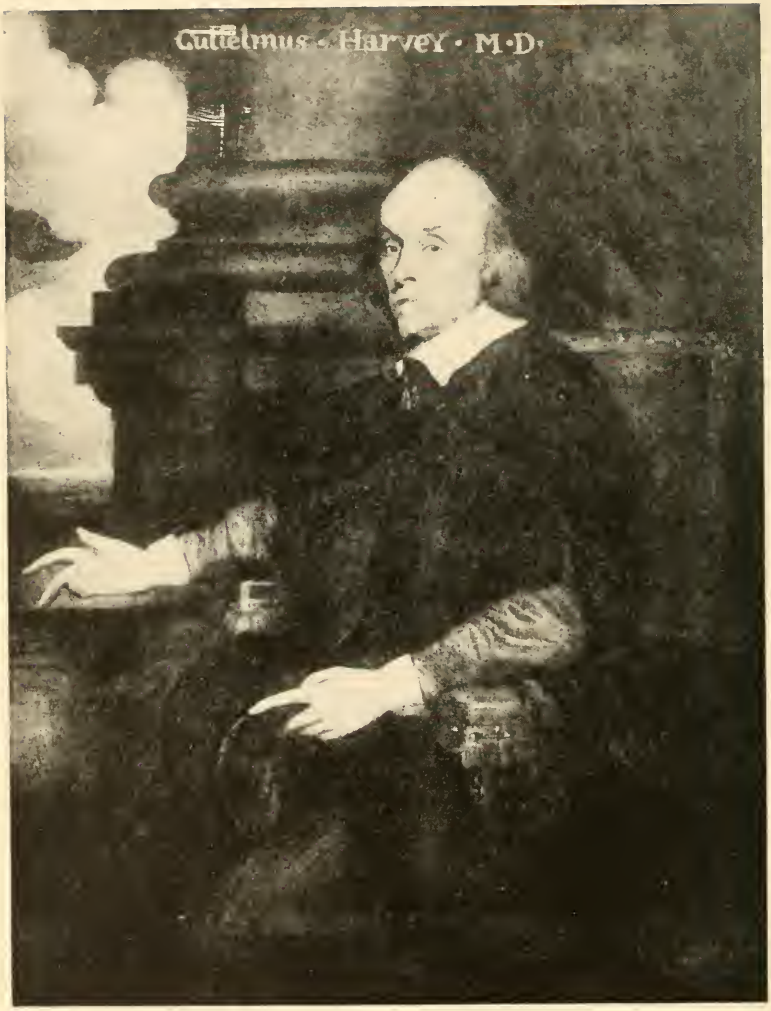
Anatomical Studies on the Motion of the Heart and Blood

William Harvey, M.D.

EXERCITATIO ANATOMICA
DE MOTU CORDIS ET SANGUINIS
IN ANIMALIBUS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TERCENTENARY EDITION

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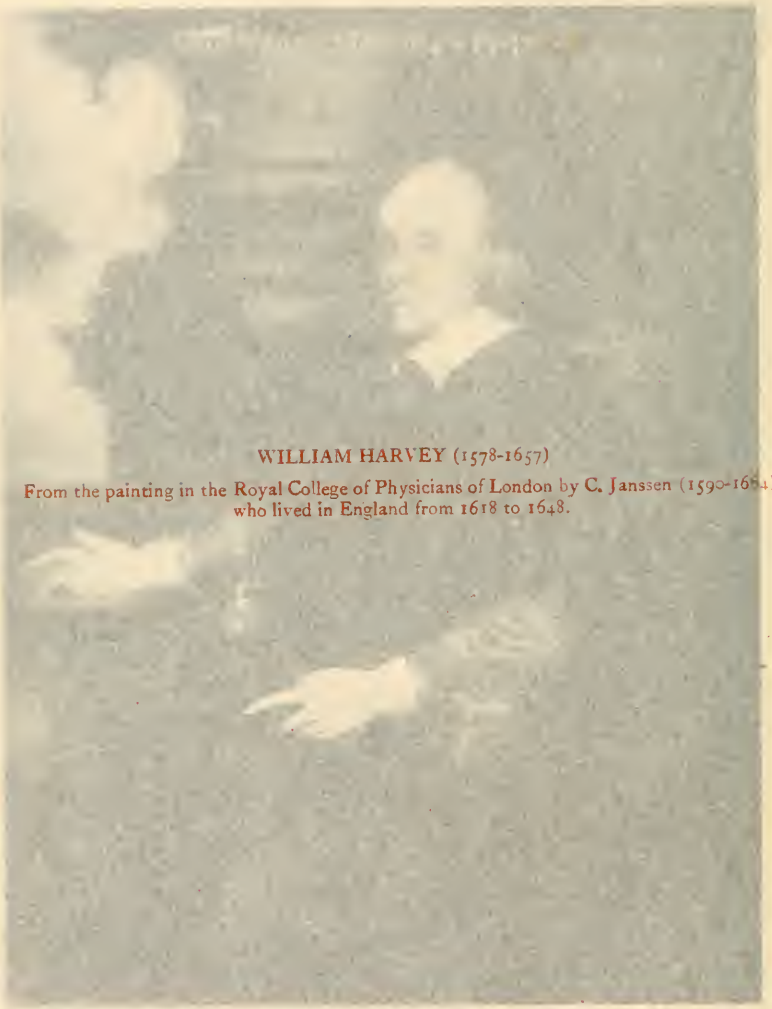
DE MOTU CORDIS
ET SANGUINIS IN ANIMALIBUS

by WILLIAM HARVEY, M.D.

With an English Translation
and Annotations by

WILLIAM HARVEY (1578–1657)
From the painting in the Royal College of Physicians of London by C. Janssen (1590–1664)
who lived in England from 1618 to 1643.

CHARLES C. THOMAS
SPRINGFIELD, ILLINOIS BALTIMORE, MARYLAND
M C M X X V I I I



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By WILLIAM HARVEY, M. D.

With an English Translation and Annotations by

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M. C M. X X V I I I

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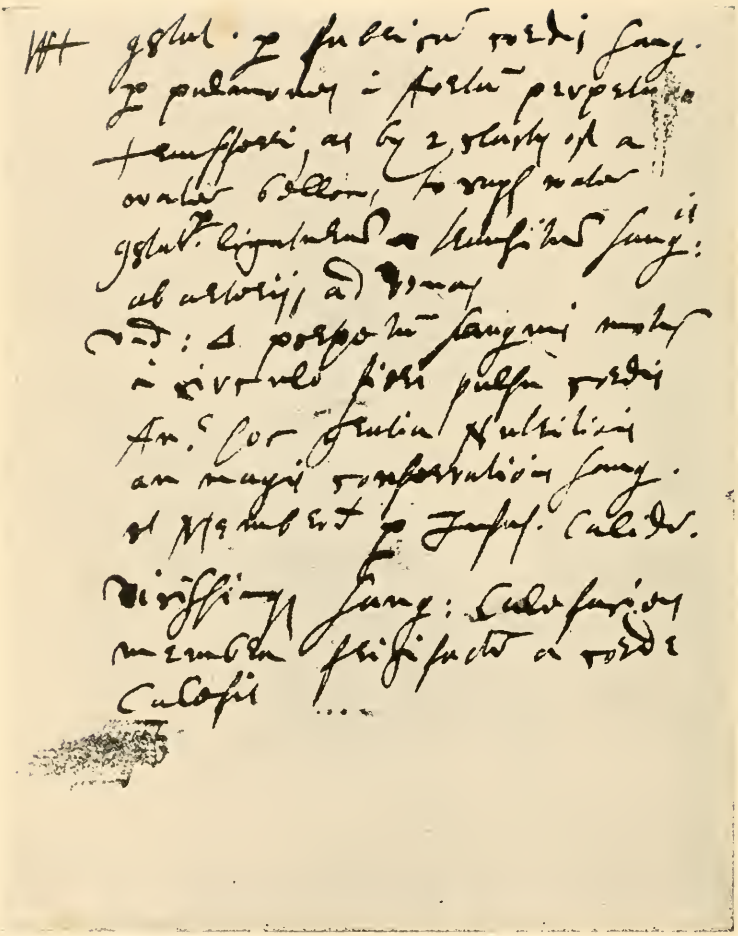


THE FIRST NOTATION OF THE DISCOVERY OF THE CIRCULATION OF THE BLOOD, IN HARVEY'S HANDWRITING

Harvey's First Note on the Circulation

This is the right hand page 80 of Harvey's *Prelectiones Anatomiae Universalis*, his 1616 Lecture Notes, discovered in the British Museum and published in 1886. It reads as follows:

WH constat per fabricam cordis sanguinem
per pulmones in Aortam perpetuo
transferri, as by two clacks of a
water bellows to rayse water
constat per ligaturam transitum sanguinis
ab arterijs ad venas
vnde Δ perpetuum sanguinis motum
in circulo fieri pulsu cordis
An? hoc gratia Nutritionis
an magis Conservationis sanguinis
et Membrorum per Infusionem calidam
vicissimque sanguis Calefaciens
membra frigifactum a Corde
Calefit

One may freely translate these rough notes:

WH demonstrates by the structure of the heart that blood is continually passed through the lungs into the aorta, as by two clacks of a water bellows to raise water. The passage of blood from arteries to veins is shown by means of a ligature. So it is proved that a continual movement of the blood in a circle is caused by the beat of the heart. Is this for the sake of nourishing or the better preservation of the blood and parts of the body by infusion of heat, the blood alternately being cooled, by heating these parts, and warmed, by the heart?

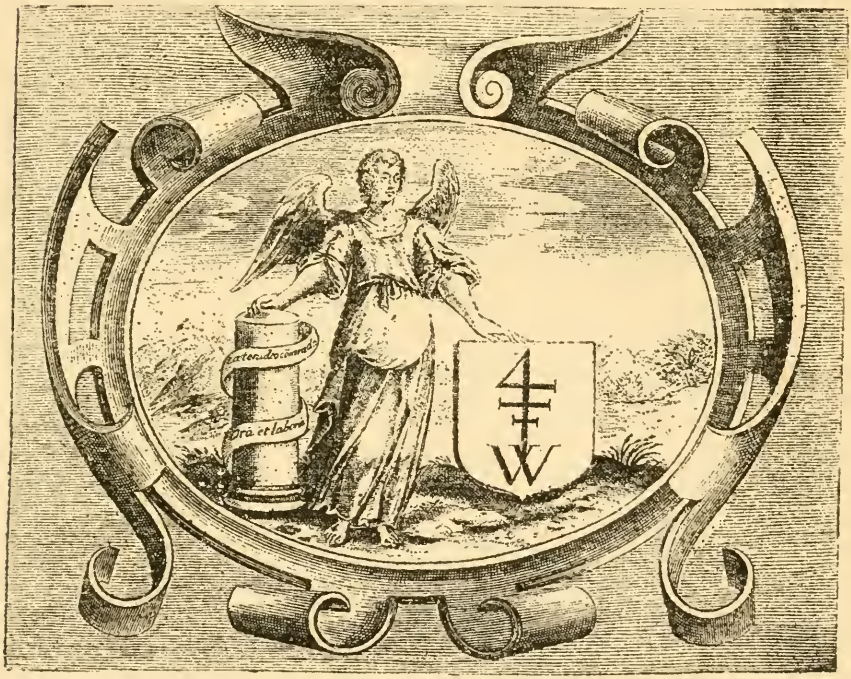
PART ONE

FACSIMILE OF THE ORIGINAL LATIN EDITION

EXERCITATIO

ANATOMICA DE MOTV CORDIS ET SANGVINIS IN ANIMALIBVS,

GVILIELMI HARVEI ANGLI,
Medici Regii, & Professoris Anatomiæ in Collegio Medicorum Londinensi.



FRANCOFVRTI,
Sumptibus GVILIELMI FITZERI.
ANNO M. DC. XXVIII.

Sereniſſimo & Inuictiſſimo

CAROLO, MAGNÆ BRITANNIÆ, FRANCIÆ, ET HYBERNIÆ REGI, FIDEI DEFENSORI.

SEreniſſime Rex,

Cor animalium, fundamentum eſt vitæ, princeps omnium, Microcoſmi Sol, à quo omnis vegetatio dependet, vigor omnis & robur emanat. Rex pariter regnorum ſuorum fundamentum, & Microcoſmi ſui Sol, Reipublicæ Cor eſt, à quo omnis emanat poteſtas, omnis gratia provenit. Quæ de motu cordis hîc ſcripta ſunt, Majeſtati tuę (vti huius ſeculi mos eſt) offerre eò magis auſus ſum, quòd ad hominis exemplum humana

mana pene omnia, & ad cordis, Regis plurima. Regi itaque non inutilis cordis ſui notitia, tanquam actionum diuinum Exemplarium : (ſic paruis componere magna ſolebant.) Poteris ſaltem Regum optime, in faſtigio rerum humanarum poſitus, vnâ operâ & humani corporis principium & Regię ſimul poteſtatis Tuę effigiem contemplari. Suſcipe itaq;, humilime precor; Sereniſſime Rex vſitata benignitate & clementia de corde noua hæc, qui ipſe nouus ſplendor huius ſeculi, & totum vere cor es, princeps virtute abundans, ac gratia; cui acceptum iure merito referimus, quicquid noſtra Anglia boni, quicquid vita noſtra iucundi, habet.

Auguſtiſſimæ Maieſtatis Tuæ

deuotiſſimus ſeruus

GVILIELMVS HARVEIVS.

Excellentiſs⁰ & Ornatiſſ. Viro D.

D. ARGENT,

COLLEGH MEDICORVM

LONDINENS. PRÆSIDI AMICO SVO ſingulari cæteriſq; Doctiſſ. Medicis Collegis ſuis amantiſſ.

S. P. D.

MEam de motu & vſu cordis, & circuitu ſanguinis ſententiam E. D. D. antea ſæpius in prælectionibus meis Anatomicis aperui novam: ſed iam per nouem & amplius annos multis ocularibus demonſtrationibus in conſpectu veſtro confirmatam, rationibus & argumentis illuſtratam, & ab obiectionibus doctiſſimorum & peritiſſimorum Anatomicorum liberatam, toties ab omnibus deſideratam, à quibuſdam efflagitatam, in lucem & conſpectum omnium hoc libello pro-

duximus. Quem niſi vobis tranſmiſſum E. D. D. minus ſperarem prodire poſſe integrum & tutum, cum pene omnium illarum obſeruationum, ex quibus aut veritatem colligo, aut errores redarguo, è vobis plurimos & fide dignos appellare poſſum teſtes, qui diſſectiones meas vidiſtis, & ocularibus demonſtrationibus eorum, quæ hic ad ſenſum palàm aſſeuero, aſſiſtere candidè & aſtipulari conſueuiſtis. Et cum contra receptam viam, per tot ſecula annorum ab innumeris, iiſq; clariſſimis doctiſſimiſque, viris tritam & illuſtratam; ſanguinem iter nouum metiri ſuum & reuoluere ſolus iſte liber affirmaret; arroganter nimis factum, ne videretur, libellum iſtum per aliquot abhinc retro annos alioquin perfectum, vel in publicum exire vel transfretare ſi permiſiſſem, ſummopere verebar: Niſi prius vobis propoſuiſſem, & per autopſiam confirmaſſem, veſtris dubiis & obiectionibus reſpondiſſem, & Præſidis ornatiſſimi cenſuram in fauorem accepiſſem. Perſuaſiſſimum veruntamen habui, quod ſi coram vobis noſtroq; Collegio tot tantiſque viris doctiſſimis nobilitatõ, propoſitum ſuſtinere potuerim, ab aliis tum demum minus pertimeſcendum, & iam illud, quod mihi

à vobis

à vobis, ob amorem veritatis, contigit vnicum ſolatium, ab omnibus aliis qui ſimiliter ſint philoſo hati non minus eſſe ſperandum. Philoſophi enim veri, qui amore veritatis & ſapientiæ flagrant, nunquam ſe tam σοφὺς, ſapientia plenos reperiunt, aut ſuo ſenſu abundant, quin veritati, à quocunque & quandocunque venerit, locum dent. Nec tam anguſti animi vt credant quamuis artem aut ſcientiam adeo omnibus numeris abſolutam & perfectam à veteribus traditã, vt aliorũ induſtriæ, & diligentiæ nihil ſit reliquum: cum profiteantur plurimi, maximam partem eorum quæ ſcimus, eorum quæ ignoramus minimam eſſe, nec ita traditionibus & præceptis quorumcunque addicti, inſervire ſe patiuntur Philoſophi, & libertatem perdũt, ne oculis propriis fidem adhibeant, nec ita in verba iurant antiquitatis magiſtræ, vt veritatem amicam in apertis relinquant, & in conſpectu omnium deſerant. Sed ſicut credulos & vanos, omnia prima facie admittere & credere, ita manifeſta ſenſui non videre, & Luce meridiana diem non agnoſcere, ſtupidos & inſenſatos pariter exiſtimant. Et non minus poetarum fabulas, & vulgi deliramenta, quam Scepticorum epochen in via philoſophica

decli-

declinare docent. Omnes item ſtudioſi, boni, honeſtique, nunquam ita paſſionibus indignationis, inuidiæ, obrui mentem ſinunt, quo minus audiant æquo animo quæ pro veritate proferantur, aut rem vere demonſtratam intelligant. nec turpe putant mutare ſententiam ſi veritas ſuadet & aperta demonſtratio: nec errores, licet antiquiſſimos deſerere arbitrantur inhoneſtum. Cum optime norint quod humanum ſit errare, decipi, & quod caſu multa reperta eſſe contingat quæ diſcere quiuis à quouis poſſit, à iuuene ſenex, à ſtulto intelligens.

Verum iſto tractatu, Collegæ Amantiſſimi, in authorum & ſcriptorum Anatomicorum nominibus, operibus & ſententiis recenſendis, exagitandis memoriam meam, & lucubrationes, multamque lectionem & magnum volumen oſtentare nolebam. Tum quod non exlibris, ſed ex diſſectionibus, non ex placitis Philoſophorum, ſed fabrica naturæ diſcere & docere Anatomen profitear. Tum quod neque è veteribus quemquam debito honore defraudare, neque è poſterioribus quemquam irritari æquum cenſeam, aut moliar. Neque cum iis qui in Anatomicis antecelluerunt, & me docuerunt, manus conſerere, aut dimicari honeſtum putem. Accedit, quod nec falſitatis crimen, in quem-

piam

piam veritatis ſtudioſum mea ſponte inurere vellẽ, nec quenquam erroris labe inſimulare. Sed ſolam veritatem ſector, & omnem tum operam, tum oleũ eò contuli, vt aliquid bonis gratum, doctis commodum, & rei litterariæ vtile in medium proferre poſſim. Valete Domini D. Excellentiſ. & Anatomico veſtro fauete

GVILIELMO HARVEO.

PROOEMIVM

Quo demonſtratur quod quæ hactenus ſcripta ſunt de motu, & vſu cordis & arteriarum minus firma eſſe.

DE cordis arteriarumque motu, pulſu, actione, vſu, & vtilitatibus cogitanti, operæpretium eſt, quæ prius ab aliis mandata ſunt literis, euoluere, quæ vulgo iactata & tradita, animaduertere, vt quæ recte dicta, confirmentur: quæ falſa diſſectione anatomica, multiplici experientia, diligenti, & accurata obſeruatione emendentur.

Pene omnes huc vſque Anatomici, Medici, & Philoſophi ſupponunt cum Galeno, eundem vſum eſſe pulſus, quem reſpirationis, & vnare tantum differre, quod ille ab animali hæc à vitali facultate manet: reliquis, vel quod ad vtilitatem, vel quod ad motus modum ſpectat ſimiliter ſe habentibus, vnde affirmant (vt Hieronymus Fabr. ab aq. p. libro ſuo de reſpiratione *nuperrime edito) quod quoniam non ſufficit pulſus cordis, & arteriarum ad ventandum, & refrigerandum; ideo à Natura pulmones circa cor fabrefactos eſſe. Hinc patet quod quæcunque dixerint priores de Syſtole, & Diaſtole, de motu cordis & arteriarum, hæc omnia ad pulmones reſpicientes eos tradidiſſe.*

Cum vero aliter ſe habeat motus, & conſtitutio cordis, quam pulmonum, aliter arteriarum, quam pectoris, alios exinde, vſus, & vtilitates exoriri veriſimile eſt, differreque plurimum cordis, &

ſimiliter

ſimiliter Arteriarum pulſus, & vſus, à pectoris & pulmonum. Si enim iſdem vſibus inſeruiant pulſus, ac reſpiratio, & in Diaſtole introſumant aërem in cauitates ſuas arteriæ (vti vulgo dicunt) & in Syſtole per eoſdem poros carnis, & cutis fuligines emittant, nec non medio tempore inter Syſtolem, & Diaſtolem aërem contineant; & quouis tempore aut aërem, aut ſpiritus, aut fuligines.. Quid itaque reſpondeant Galeno, qui librum ſcripſit, Natura ſanguinem contineri in arteriis, & nihil præter ſanguinem, nimirum neque ſpiritus, neque aërem, ſicut ab experimentis, & rationibus in eodem libro *facile colligere licet. Et ſi in Diaſtole replentur arteriæ ab aëre introſumpto, in maiori pulſu, maiori ſubeunte aëris copia: ergo magno exiſtente pulſu, ſi totum corpus in balneum immerſeris, vel aquæ, vel olei, neceſſe eſt pulſum ſtatim aut minorem eſſe, aut tardiorem multo: cum per corpus ambientis balnei, aërem intra arterias permeare difficilius ſit, ſi non impoſſibile. Similiter, cum omnes arteriæ tàm profundæ, quàm cutaneæ, eodem tempore, & pari velocitate diſtendantur; quomodo poterit aër tàm libere, & celeriter per cutem, carnem, habitumque corporis in profundum pertranſire, quam per cuticulam ſolam. Et quomodo Embryonum arteriæ forinſecus in cauitates ſuas aërem per ventrem maternum, & per corpus vteri attrahant? Vel quomodo Phocæ, Balenæ, Delphines, cetaceum omne genus, & piſces omnes in profundo maris arteriarum ſuarum Diaſtole, & Syſtole, per immenſam aquæ maſſam celeri pulſu aërem introſumunt, & emittunt. Dicere vero quod aërem implantatum in aqua abſorbeant, & in aquam fuligines ſuas reddant, figmento haud abſimile. Et ſi in Syſtole arteriæ per poros carnis, & cutis, fuligines è cauitatibus illorum expellunt, cur non item ſpiritus, quos dicunt etiam in illis contineri, cum ſpiritus multo tenuiores fuliginibus ſint. Et ſi cum in Syſtole, tum in Diaſtole aërem arteriæ accipiunt, & reddunt, vti pulmones in reſpiratione; cur non & hoc faciunt inflicto per*

arteriotomiam vulnere? sectione trachæa per vulnus, aërem ingredi, regredi duobus contrariis motibus, palam est: Sectâ vero arteriâ statim vno continuo motu sanguinem vi protrudi, & non aërem, vel ingredi, vel regredi manifestum est. Si pulsus arteriarum partes corporis refrigerant, & euentant vti pulmones ipsum cor; quomodo dicunt vulgo arterias à corde in partes singulas vitalem sanguinem differre refertissimum spiritibus vitalibus? qui partium calorem faueant, sopitum suscitent, & quasi absumptum resarciant, & quomodo (si ligaueris arterias) statim partes non modo torpent, frigent, & quasi pallidæ cernuntur, sed & ali tandem desinunt, quod secundum Galenum contingit, quia calore, qui per omnes partes superne à corde confluxerat, priuatæ sint: cum hinc pateat magis arterias calorem partibus deferre, quam refrigerium, & euentationem. Præterea quomodo Diastole simul spiritus à corde attrahat, ad calefaciendas partes, simulq; ab externo refrigerium? Amplius tametsi iisdem vsibus pulmones, arterias, & cor inseruire aliqui affirment, tamen cor spirituum officinam esse, & arterias spiritus continere, transmittere etiam dicunt: Pulmones autem spiritus facere, aut retinere contra Columbi opinionem, negant. Quin & cũ Galeno, quod sanguis contineatur in arteriis, & non spiritus, contra Erasistratum asseuerant. Videntur istæ opiniones ita inter se pugnare, & sese inuicem refellere, vt omnes non merito sint suspectæ. Sanguinem in arteriis contineri, & arterias solum sanguinem deferre tum experimento Galeni, tum in arteriotomia, tum in vulneribus manifestum est, cum ab vna arteria dissecta, hoc etiam Galenus affirmat plurimis in locis vnius semihoræ spatio totam massam sanguinis ab vniuerso corpore, magna, & impetuosa profusione exhaustam fore, experimentum Galeni tale est. Si (*inquit*) funiculo arteriam vtrinq; ligaueris & medio rescisso secundum longitudinem, quod inter duas ligaturas in arteriis comprehensum erit, nihil præter sanguinẽ esse reperies: *& sic probat sanguinẽ solum continere. Vnde etiã similiter nobis ratiocinari licet:*

Galen. lib. quod sangui. cont. in arteriis.

licet: Si eundem ſanguinem, qui venis ſimiliter ligatis, & reſciſſis ineſt, inueneris in arteriis (quem in mortuis, & aliis animalibus ſæpius ego expertus ſum) eâdem ratione ſimiliter concludere nos poſſumus, arterias eundem ſanguinem, quem vena, & nihil præter eundē ſanguinem continere. Aliqui dum diſſoluere difficultatem tentant, ſpirituoſum, & arterioſum eſſe ſanguinem affirmantes, tacite concedunt, arteriarum munus eſſe ſanguinem à corde in vniuerſum corpus deferre, & repletas ſanguine arterias eſſe: Spirituoſus n. ſanguis, non minus ſanguis eſt: Etiam ſanguis prout ſanguis, & qui in venis fluit, eum ſpiritibus imbui nemo negat. Quod ſi, qui in arteriis eſt ſanguis vberiori ſpirituum copia turgeat, tamen exiſtimandum eſt hos ſpiritus à ſanguine inſeparabiles eſſe, ſicut illi in venis, & quod ſanguis, & ſpiritus vnum corpus conſtituant (vt ſerum, & butyrum in lacte, aut calor in aquâ calidâ) quo corpore replentur arteriæ & cuius corporis diſtributionem à corde arteriæ præſtant, & hoc corpus nihil aliud, quam ſanguis eſt. Si vero hunc ſanguinem in arteriis, è corde per arteriarum Diaſtolem attrahi dicunt, videntur aſtruere, quod arteriæ ſuâ diſtentione ſanguine iſto repleantur, & non aëre ambiente, vti prius: Nam ſi etiam aëre ab ambiente repleri dicant, quomodo & quando recipient è corde ſanguinem? Si in Syſtole id fiat, continget impoſſibile; repleri arterias, cum attrahantur, vel repleri, & non diſtendi; Sin autem in Diaſtole, in duos vſus contrarios, & ſanguinē, & aërem, & calorem, & frigus ſimul recipient; quod eſt improbabile. Amplius cum affirmant, ſimul Diaſtolē cordis, & arteriarū eſſe, & ſimul Syſtolē, alterū eſt inconueniēs. Quomodo n. cum ſimul diſtenduntur duo corpora ſit inuicē cōnata, alterū ab altero attrahat, vel cū ſimul cōtrahuntur, alterū ab altero recipiat aliquid? Inſuper forſan impoſſibile eſt, aliquid poſſe aliud corpus ita in ſe ipſū attrahere vt diſtendatur, cū diſtendi ſit pati niſi vt ſpongia prius vi ab externis conſtricta, dū redeat ad conſtitutionē ſuam naturalē. Tale autē aliquid in arteriis poſſe eſſe, difficile eſt fingere. Sed arterias diſtendi, quia replentur, vt ſacculi, & vtres,

atq; non repleri, quia diſtenduntur vt folles, facile, & aperte demonſtrare me poſſe, & palam ante hac demonſtraſſe exiſtimo: Attamen libr. quod ſang. cont. in arter. *Galeni experimentum in contrarium ſic ſe habet. Arteriam nudatam ſecundum longitudinem incidit, calamumque, vel concauam, per viam fiſtulam immittit, quo & ſanguis exilire non poſſit, & vulnus obturetur.* Quoaduſque (*inquit*) ſic ſe habet, arteria tota pulſabit: cum primum vero obductum filum ſuper arteriam, & fiſtulam in laqueum cõtrahens arteriæ tunicas calamo obſtrinxeris, non amplius arteriam vltra laqueum palpitare videbis. *Nec ego feci experimentum Galeni, nec recte poſſe fieri viuo corpore ob impetuoſi ſanguinis ex arteriis eruptionem puto, nec obturabit ſine ligatura vulnus fiſtula: & per fiſtulæ cauitatem vlterius proſilire ſanguinem non dubito, tamen hoc experimento & probare videtur Galenus facultatem pulſificam per tunicas arteriarum, à corde manare, & quod arteriæ dum diſtendantur, ab illâ facultate pulſifica repleantur, quia diſtenduntur vt folles, non diſtendantur, quia replentur, vt vtres. Sed & in arteriotomia, & vulneribus contrarium manifeſtum eſt: ſanguis enim ſaliendo ab arteriis profunditur cum impetu, modo longius, modo propius viciſſim proſiliendo, & ſaltus ſemper eſt in arteriæ Diaſtole & non in Syſtole. Quo clare apparet, impulſu ſanguinis arteriam diſtendi. Ipſa enim dum diſtenditur, non poteſt ſanguinem tanta vi proijcere, potius aërem in ſe per vulnus attrahere deberet, ſecundum ea, quæ vulgò de arteriarum vſu iactata ſunt. Nec craſſities tunicarum arteriæ nobis imponat, facultatem pulſificam prouenire à corde per ipſas tunicas: Nam quibuſdam animalibus arteriæ à venis nihil differunt, & extremis partibus hominis, & paruis diſſeminationibus arteriarum quales in cerebro, manu &c. nemo per tunicas, arterias à venis poterit diſtinguere: eadem enim vtriſq; tunica: in aneuriſmate præterea ex inciſa vel exeſa arteria genito, eadem omnino pulſatio*

cum

cum reliquis arteriis, & tamen non habet tunicam arteriæ. Hoc mecum doctiſſimus Riolanus lib. 7. *atteſtatur. Neq; eundem vſum pulſus, ac reſpirationis quis exiſtimet, quod iiſdem cauſis vti, reſpiratio, crebriores, maiores, celeriores fieri cernat, vti curſu, ira, balneo, aut quouis calfaciente (vt dicit Galenus) Nam non ſolum illud experimentum eſt in contrarium (quod ſoluere Galenus nititur) cum ab immodica repletione pulſus exiſtant maiores, reſpirationes minores; Sed & in pueris pulſus frequentes, cum reſpiratio interim rara. Similiter in timore, & curis, & anxietate animi, imo aliquibus in febribus pulſus celeres, frequentes, reſpirationes vero tardiores. Hæc & huiuſmodi incommoda poſitas opiniones de pulſu, & vſu arteriarum, conſequuntur: non minus forſan etiam ea, quæ de vſu, & pulſu cordis affirmantur, difficultatibus plurimis & inextricabilibus implexa ſunt. Cor affirmant vulgo fontem, & officinam vitalis ſpiritus eſſe, quibus vitam ſingulis partibus largiatur, & tamen negant dextrum ventriculum ſpiritus facere, ſed præbere duntaxat alimentum pulmonibus, vnde dicunt piſcibus deeſſe dextrum ventriculum cordis, & omnino omnibus deeſt quibus non ſunt pulmones: Et q dexter ventriculus cordis, pulmonũ gratia ſit.*

1. *Cur (quæſo) cum eadem pene conſtitutio ſit vtriuſq; ventriculi, eadem fabrica fibrarum, lacertulorum, valvularum, vaſorum, auricularum, & eodem vterq; in diſſectionibus referciatur ſanguine, ſimiliter nigricante, ſimiliter grumeſcente: Cur (inquã) cum eadem ſit vtriuſq; actio, motus pulſus, variis eos vſibus, tam differentibus, exiſtimemus deſtinatos fuiſſe? Si valvulæ tricuſpides tres ſub dextri ventriculi ingreſſu, impedimento ſint ſanguinis regreſſui in venam cauam, & ſi ſemilunares tres illæ in orificio arteriosæ venæ vt ſanguinis regreſſum impedirent factæ ſint: cur, cum ſimiliter ſe habeant. ſiniſtro ventriculo ſimiliter ſanguinis tum egreſſui, tum regreſſui impediendo factas eſſe, negemus.*

2. *Et cum magnitudine, forma, ſitu, omnino eodem pene modo*

ſiniſtro

ſiniſtroſe habeant ventriculo, quo in dextro, cur dicunt hic ſpiritum egreſſui, & regreſſui impedimento eſſe in dextro vero ſanguinis. Idem organon ſimile non videtur ſanguinis, & ſpirituum motus ſimiliter impedire apte poſſe.

3. *Et cum meatus, & vaſa ſibi invicem reſpondeant magnitudine, videlicet, vena arterioſa, & arteria venoſa; cur vnum priuato vſui deſtinetur, videlicet alendis pulmonibus, alterũ publico.*

4. *Et quomodo probabile eſt (vti notauit Realdus Columbus) tanto ſanguine opus eſſe ad nutritionem pulmonum, cum hoc vas, vena videlicet arterioſa, exuperat magnitudine vtrumq; ramum diſtributionis venæ cauæ deſcendentis cruralem.*

5. *Et (quæſo) cum pulmones tam propè ſint, & vas tam amplum exiſtat, & ipſi continuo motu, quid eſt quod dextri ventriculi pulſu opus ſit? & quid eſt quod Natura, gratia alendorum pulmonum, alterum ventriculum cordi adiungere neceſſe habeat.*

Cum dicunt ſiniſtrum ventriculum è pulmonibus, & dextro cordis ſinu materiam attrahere, ad ſpiritus condendos; aërem videlicet & ſanguinem, & pariter in aortam ſpirituoſum ſanguinem diſtribuere: & hinc fuligines, videlicet retro per arteriam venalem remitti in pulmones, illinc ſpiritus in aortam. Quid eſt quod ſeparationem facit, & quod modo huc illuc ſpiritus fuligines citra permiſtionem aut confuſionem commeant. Si tricuſpides mitrales non impediunt egreſſum fuliginum ad pulmones, quomodo impedient aëris? Et quomodo ſemilunares prohibebunt regreſſum ſpirituum (ſubſequente Diaſtole cordis) ab aorta? Et omnino, quomodo dicunt per arteriam venalem ſpirituoſum ſanguinẽ diſtribui è ventriculo ſiniſtro in pulmones, nec interim impediant tricuſpides? cum affirmarint aërem per idem vas à pulmonibus in vẽtriculum ſiniſtrũ ingredi, cui⁹ egreſſui tricuſpides illæ valuulæ impedimento eſſe voluerunt. Deus bone! Quomodo tricuſpides impediunt aëris egreſſum, & non ſanguinis.

Amplius

Amplius, cum venam arterioſam, vas amplum, magnum cum tunica arteriæ factum, non niſi priuato, & vni vſui (videl. alendis pulmonibus) deſtinarint: Cur arteriam venalem vix pari magnitudine cum tunica venæ molli, laxa, pluribus vſibus, tribus, vel quatuor videlicet fabrefactam aſſeuerant: volunt enim per ipſam aerem è pulmonibus in ſiniſtrum ventriculum permeare: volunt ſimiliter è corde in pulmones fuligines per ipſam remeare: volunt ſpirituoſi ſanguinis portionem à corde per ipſam in pulmones ad ipſos refocillandos diſtribui.

Si fuligines & aerem à corde illas, ad cor hunc per eundem tubulum volunt tranſmitti; tam cõtrariis motibus, & vſibus vnum vas, & vnam viam fabricare Natura ſolita non eſt, nec videre vſpiam contigit.

Si fuligines, ſi aerem hac via permeare, remeare contendunt, vt per Bronchia pulmonum quare exſecta, vel inciſa arteria venoſa, neque aerem, neque fuligines reperire in diſſectione poſſumus, & vnde ſemper refertam craſſo ſanguine arteriam venoſam iſtam videmus, & nunquam aere; cum in pulmonibus, & aerem remanentem cernimus?

Si quis experimentum Galeni faceret, & cani adhuc viuenti trachæam incideret, & follibus pulmones aere impleret per vim, & diſtẽtos ligaret fortiter; Idem mox diſſecto pectore multam aeris copiam in pulmonibus vſque ad extimam illorum tunicam inuenerit, ſed neq; in arteria venoſa, neque in ſiniſtro ventriculo cordis quidquam. Si aerem è pulmonibus, in cane viuente, aut cor attraheret, aut pulmones tranſmitteret, multo magis hoc experimento id facere deberent. Imo in adminiſtratione Anatomica inflatis cadaueris pulmonibus, etiam aerem ſtatim huc ingredi (ſi vlli eſſent meatus) quis dubitaret? Tam magni vero faciunt hunc vſum arteriæ venoſæ, videlicet ad aerem è pulmonibus cordi deferendum: vt Hieronym. Fabr. ab. aq. p. huius vaſis cauſa pulmones factos fuiſſe, & hanc eſſe præcipuam pulmonum particulam contendat.

Sed amabo, ſi aeri deferendo arteria venoſa condita ſit, cur eius conſtitutio eſt vena?

Fiſtulis potius opus eſſet Natura (& quidem quales Bronchia ſunt annularibus, vt ſemper pateant, & neque concidant, & vt omnino vacua ſanguine permaneant ne humor aeris tranſitum impediat, vti manifeſtum eſt, quando pulmones pituita Bronchiis vel infarcta, vel paululum admiſſa laborant) ſibilo, & ſtrepitu oborto dum reſpiramus.

Minus toleranda illa opinio, qua cum duplicem materiam (aereā, & ſanguineam) neceſſariam eſſe ad ſpiritus vitales efficiendos ſupponit, ſanguinem per mediaſtini cordis cæcas poroſitates de dextro in ſiniſtrum ventriculum tranſudare, aerem per magnum vas Arteriam venoſam è pulmonibus attrahi contendit: Et proinde in ſepto cordis poroſitates plures eſſe producendo ſanguini accommodatas. Sed me hercule poroſitates nullæ ſunt, neque demonſtrari poſſunt.

Septi enim cordis ſubſtantia denſior, & compactior eſt quauis altera corporis particula, exceptis oſſibus, & neruis. Sed ſi adeſſent foramina, quomodo (cum ſimul vterque ventriculus diſtenditur, & dilatatur) alterum ab altero quidpiam, aut ſiniſtrum ſanguinem è dextro exhaurire poſſibile eſt? Et cur non potius dextrum ſpiritus ex ſiniſtro, quam ſiniſtrum ſanguinem è dextro ventriculo per eadem foramina euocare crediderim. At mirum, & incongruum certe, ſanguinem per cæcos obſcuroſque ductus, & aerem per patentiſſimos eodem inſtanti, commodius attrahi. Et cur quæſo pro ſanguinis tranſitu in ſiniſtrum ventriculum ad cæcas, & inuiſibiles poroſitates incertas, obſcuras confugiunt, quando adeſt per arteriam venoſam tam patens iter? mirum mihi certe eſt, quod per cordis ſeptum, craſſum, durum, denſum, compactiſſimum viam facere, vel fingere potius maluerunt, quam per patens vas venoſum, aut etiam per pulmonū ſubſtantiam raram, laxam, molliſſimam, ſpongioſam. Præterea ſi per ſepti ſubſtantiam ſanguis permeare potuiſſet, aut è ventriculis imbibi, quid opus eſſet vena, & arteria coronalis ramulis ad ipſius ſepti nutritionem diuaricatis? Quod notatu digniſſimum, ſi in fœtu (quando omnia ra-

riora

riora, molliora) *Natura coacta fuit per foramen ouale ſanguinem in ſiniſtrum ventriculum è vena caua per arteriam venoſam traducere. Quomodo veriſimile poſſit eſſe quod in adulto per cordis ſeptum iam denſius ætate factum tum commode nulloque negotio transfundat.*

Andreas Laurentius lib. 9. cap. 11. Quæſtione 12. *authoritate Galeni* de Io. affect. lib. 6. cap. 7. *& experientia Hollerii fulius, aſſerit, & probat è cauitate pectoris ſeroſitates, & pus Empyricorum in arteriam venoſam abſorptum per ſiniſtrum ventriculum cordis, & per arterias cum vrina, vel cum facibus alui poſſe expelli recenſet. quinetiam in confirmationem caſum cuiuſdam Melancholici, qui ſæpius deliquium animi paſſus à paroxyſmo liberatus erat emiſſione vrinæ turbidæ, fœtidæ, acris: quo genere morbi tandem confectus, diſſecto cadauere, talis ſubſtantia, qualem mingebat, neque in veſica, neque in renibus vſtiam apparebat, ſed in cordis ſiniſtro ventriculo, & cauitate pectoris plurima: vnde gloriatur ſe horum affectuum talem prædixiſſe cauſam. Ego autem non poſſum non mirari, cum ipſe materiam heterogeneam poſſe eodem tractu euacuari diuinarat, & prædicauerat: quod iiſdem viis ſanguinem è pulmonibus in ſiniſtrum ventriculum ſecundum naturam deduci conuenienter cernere, aut aſſeuerare non potuit, aut noluit.*

Itaque ex his, & huiuſmodi plurimis patet, cum ea quæ dicta antehac à prioribus de motu, & vſu cordis, & arteriarum, aut inconuenientia, aut obſcura, aut impoſsibilia diligentius conſiderati appareant, vtile proinde admodum erit paulo penitius rem introſpicere, arteriarum, & cordis motus non ſolum in homine, ſed & aliis vniuerſis animalibus cor habentibus contemplari: Quin etiam viuorum diſſectione frequenti, multaque autopſia veritatem diſcernere, & inueſtigare.

EXERCITATIO
Anatomica,
DE MOTV CORDIS
ET SANGVINIS IN ANIMALIBVS.

Caput Primum.

Cauſa, quibus ad ſcribendum Author permotus fuerit.

CVM multis viuorum diſſectionibus (vti ad manum dabantur) animum ad obſeruandum primũ appuli; quo cordis motus vſum, & vtilitates in animalibus per autopſiam, & non per libros aliorumque ſcripta inuenirem: Rem arduam plane, & difficultatibus plenam cõtinuo reperi, vt (cum Fracaſtorio) motum cordis ſoli Deo cognitum fuiſſe, penè opinarer. Nec enim quomodo Syſtole, aut Diaſtole fieret, nec quando, aut vbi dilatatio, & conſtrictio exiſteret, recte potui internoſcere, propter celeritatem ſcilicet motus qui in multis animalibus, nictu oculi, quaſi traiecto fulgure, ſe in conſpectum exhibuit, & ſubtraxit illico, ita vt modo hinc Syſtolen, illinc Diaſtolen, modo è contra, modo varios, modo confuſos fieri motus me exiſtimabam cernere: vnde animus mihi fluctuabat, nec quid vel ipſe ſtatuerem, vel aliis crederem habebam, & motum cordis eſſe qualis Euripi fluxus, & refluxus Ariſtoteli, Andream Laurentium ſcripſiſſe non mirabar.

Tandem maiori indies, & diſquiſitione, & diligentia vſus, multa frequen-

ſic quenter, & varia animalia viua introſpiciendo, multis obſeruationibus collatis, & rem attigiſſe, & ex hoc labyrintho me extricatum euaſiſſe, ſimulque motum, & vſum cordis, & arteriarum, quæ deſiderabam, comperta habere me exiſtimabam. Ex quo non ſolum priuatim amicis, ſed etiam publice in prælectionibus meis anatomicis, Academico more, proponere meam in hac re ſententiam non verebar.

Quæ cum aliis (vti fit) placebat, aliis minus: hi conuellere, calumniari, & vitio vertere, quod à præceptis, & fide omnium Anatomicorum diſceſſerim: Illi rem nouam cum inquiſitu dignamtum maxime vtilem fore confirmantes, plenius ſibi explicatam poſcere. Tandem amicorum precibus, vt omnes meorum laborum participes fierent, partim etiam aliorum permotus inuidia qui dicta mea iniquo animo accipientes, & minus intelligentes, me publice traducere conabantur, vt omnes de me, & de re ipſa iudicium ferant, hæc typis mandare publice coactus fui: Sed & eo libentius, quod Hieronym. Fabr. ab aq. p. cum ſingulas pene animalium particulas, accurate, & docte peculiari tractatu delineauerat, ſolum cor intactum reliquit. Denique vt ſi quid reipub. literariæ ex opera mea vtile, & commodum hac in parte accederet, forſan recte feciſſe me conſtaret, nec alii omnino inertem me vixiſſe viderent, & quod ſenex ait in Comœdia (*Nunquam quiſquam ita bene ſubducta ratione ad vitam fuit,*

„ *Quin res, ætas, vſus aliquid apportet noui,*

„ *Aliquid admoneat, vt illa quæ te ſcire credas, neſcias.*

„ *Et quæ tibi putaris prima in experiundo repudies.*)

Illud forſan in cordis motu eueniat nunc, aut alii hinc ſaltem, hac data via, felicioribus freti ingeniis, rei rectius gerendæ, & melius inquirendi occaſionem capient.

CAPVT II.

Ex viuorum diſſectione, qualis ſit Cordis motus.

PRimum itaque in Cordibus, omnium adhuc viuentium animalium aperto pectore, & diſſecta capſula, quæ cor immediate circũeludit obſeruare licet. Coraliquando mouere, aliquando quieſcere, & eſſe tempus in quo mouetur, & in quo motu deſtituitur.

Hæc manifeſtiora in cordibus frigidorum animalium, vt bufone, ſerpentibus, ranis, cochleis, gammaris, cruſtatis conchis, ſquillis, &

piſciculis omnibus: Fiunt etiam omnia manifeſtiora in cordibus aliorum, vt canis, porci, ſi eo vſque attente obſeruaueris quoad emori cor, & languidius moueri, & quaſi extingui incipiat: tum etenim tardiores, & rariores ipſius motus fieri, & longiores quietes, cernere aperte, & clare poteris, & motus qualis ſit, & quomodo fiat, commodius intueri, & diiudicare licet. In quiete, vt in morte cor laxum, flaccidum, eneruatum, inclinatum quaſi iacet.

In motu, & eo quo mouetur, tempore tria præ cæteris animaduertenda.

I. Quod erigitur cor, & in mucronem ſe ſurſum eleuat, ſic vt illo tempore ferire pectus, & foris ſentiri pulſatio poſſit.

II. Vndique contrahi, magis vero ſecundum latera, ita, vti minoris magnitudinis, & longiuſculum, & collectum appareat. Cor anguillæ exemptum, & ſuper tabulam aut manum poſitum hoc facit manifeſtũ: eque etiam appatet in corde piſciculorum, & illis frigidioribus animalibus, quibus cor coniforme, aut longiuſculum eſt.

III. Comprehenſum manu cor eo quo mouetur tempore, duriuſculum fieri, à tentione autem illa duritiei eſt, quemadmodum ſi quis lacertos in cubitu manu comprehendens, dum mouent digitos, illos tendi, & magis renitentes fieri percipiat.

IV. Notandum inſuper in piſcibus, & frigidioribus ſanguineis animalibus, vt ſerpentibus, ranis, &c. illo tempore, quo mouetur cor albidioris coloris eſſe, cum quieſcit à motu caloris ſanguinei ſaturum cerni.

Ex his mihi videbatur manifeſtum; Motum cordis eſſe tentionem quandam ex omni parte, & ſecundum ductum omnium fibrarum, & conſtrictionem vndique, quoniam erigi, vigorari, minorari, & dureſcere in omni motu videtur, ipſiuſque motum eſſe, qualem muſculorũ, dum contractio fit ſecundum ductum partium neruoſarum, & fibrarum, muſculi enim cum mouentur, & in actu ſunt vigorantur, tenduntur, ex mollibus duri fiunt, attolluntur, increſſantur, & ſimiliter Cor.

Ex quibus obſeruatis rationi conſentaneum eſt, Cor eo quo mouetur tempore, & vndique conſtringitur, & ſecundum parietes increſſeſcit: ſecundum ventriculos coarctari, & contentum ſanguinem protrudere, quod ex quarta obſeruatione ſatis patet, cum in ipſa tenſione ſua, propterea quod ſanguinem in ſe prius contentum expreſſerit, albeſcit, & denuo in laxatione, & quiete, ſubingrediente de nouo ſanguine in ven-

in ventriculum, redit color purpureus, & sanguineus cordi. Verum nemo amplius dubitare poterit, cum vsque in ventriculi cauitatem inflicto vulnere, singulis motibus, siue pulsationibus cordis in ipsa tensione prosilire cum impetu foras contentum sanguinem viderit.

Simul itaque hæc, & eodem tempore contingunt, tensio cordis, mucronis erectio', pulsus, qui forinsecus sentitur ex allusione eius ad pectus, parietum incrassatio & contenti sanguinis protrusio cum impetu à constrictione ventriculorum.

Hinc contrarium vulgariter receptis opinionibus, apparet, cum eo tempore, quo cor pectus ferit, & pulsus foris sentitur; vna cor distendi secundum ventriculos; & repleri sanguine putetur, quanquam contra rem se habere intelligas, videlicet cor dum contrahitur inaniri. Vnde qui motus vulgo cordis Diastole existimatur, reuera Systole est. Et similiter motus proprius cordis; Diastole non est, sed Systole, neque in Diastole vigoratur cor, sed in Systole, tum enim tenditur, mouetur, vigoratur.

Neque omnino admittendum illud; tametsi diuini Vesalii adducto exemplo confirmatum; De vimineo circulo scilicet ex multis iunctis pyramidatim iunctis, cor secundum fibras rectas tantum moueri; Et sic dum apex ad basin appropinquat, latera in orbem distendi, & cauitates dilatari, & ventriculos cucurbitulæ formam acquirere, & sanguinem introsumere, nam secundum omnem quem habet ductum fibrarum, cor eodem tempore tenditur, constringitur, & potius incrassari, & dilatari parietes, & substantiam, quam ventriculos; & dum tenduntur fibræ à cono ad basim, & cor vna ad basin trahunt, non in orbem lateræ cordis inclinarent, sed potius contrarium, vti omnis fibra in circulari positione dum contrahitur versus rectitudinem. Et sicut omnes musculorum fibræ, dum contrahuntur & in longitudine abbreuiantur, ita secundum latera distenduntur, & eodem modo quo in musculorum ventribus incrassantur, adde, quod non solum in motu cordis per directionem, & incrassationem parietum contingit ventriculos coarctari, sed vlteriut eo quod fibræ illæ siue lacertuli, in quibus solum fibræ rectæ (in patiete enim omnes sunt circulares) ab Aristotele Nerui dictæ, quæ vario in ventriculis cordis maiorum animalium, dum vna contrahuntur, admirabili apparatu, omnia interiora latera veluti laqueo inuicem compelluntur, ad contentum sanguinem maiori robore expellendum.

Neque

Neque verum eſt ſimiliter, quod vulgo creditur, cor vllo ſuo motu, aut diſtentione ſanguinem in ventriculis attrahere, dum enim mouetur, & tenditur, expellit: dum laxatur, & concidit, recipit ſanguinem eo modo, quo poſtea patebit.

CAPVT III.

Arteriarum motus qualis ex viuorum diſſectione.

VLterius in cordis motu obſeruanda veniunt hæc, quæ ad arteriarum motus, & pulſationes ſpectant.

I. Eo tempore quo cordis fit tentio, contractio, percuſſio pectoris, & omnino Syſtole, Atteriæ dilatãtur, pulſum edunt, & in ſua ſunt Diaſtole: Similiter eo tempore quo dexter ventriculus contrahitur, & protrudit contentum ſanguinem, vena arterioſa pulſat, & dilatatur ſimul cum reliquis arteriis corporis.

II. Quando ſiniſter ventriculus ceſſat moueri, pulſare, & contrahi: ceſſat pulſus arteriarũ; imo quando languidius tenditur, pulſus in arteriis vix perceptibilis, & ſimiliter ceſſante dextro in vena arterioſa.

III. Item ſecta quauis arteria, vel perforata in ipſa tentione ventriculi ſiniſtri propellitur foras ſanguis ex vulnere cum impetu. Similiter ſecta vena arterioſa eodem tempore, quo dexter ventriculus tenditur, & contrahitur, exinde cum impetu ſanguinem proſilire videbis.

Similiter etiam in piſcibus ſecta fiſtula, quæ è corde in bronchia ducit, quo tempore cor tendi, & contrahi videbis, eo vna etiam ſanguinem exinde pertrudi cum impetu.

Similiter denique cum in omni arteriotomia ſanguis proſiliendo exeat modo longius modo propius ſaltum fieri in arteriarum Diaſtole, & quo tempore cor pectus ferit, comperies: atque hoc nimirum eo tempore quo cor tendi, & contrahi apparet, & in ſua eſſe Syſtole erectione, vnaque ſanguis expellitur eodem motu.

Ex his videtur manifeſtum contra communia dogmata, quod arteriarum Diaſtole ſit eo tempore, quo cordis Syſtole: & arterias repleri, & diſtendi, propter ſanguinis à conſtricticne ventriculorum cordis immiſſionem, & intruſionem; quin etiam diſtendi arterias, quia replentur vt vtres, aut veſica; non repleri, quia diſtenduntur vt folles. Et eadem de cauſa vniuerſi corporis arteriæ pulſant, videlicet, à tenſione ſiniſtri cordis ventriculi, ſicut vena arterioſa à dextri.

Denique

Denique arteriarum pulſum fieri ab impulſu ſanguinis è ventriculo ſiniſt o: eodem pacto, quo cum quis in chirothecam inflat, omnes digitos ſimul, & vna diſtendi, & pulſum æmulari: etenim ſecundum cordis tentionem pariter pulſus fiunt maiores, vehementiores, frequentes, celeres, rythmum, & quantitatem, & ordinem ſeruantes, nec eſt expectandum, vt propter motum ſanguinis tempus inter conſtrictionem cordis, & arteriarum (præcipue magis diſtantium) dilationem intercedat, ne fiant ſimul, cum eodem modo ſe habet, vt in inflatione chirothecæ, aut veſicæ, quod per plenum, (vt per tympanum, & in longis lignis) ictus, & motus ſimul ſunt in vtroque extremo, & quod Ariſtoteles: *Palpitat intravenas* (arterias intelligit) *ſanguis omnium animalium pulſuque ſimul vndique mouetur, ſic pulſant venæ omnes & ſimul inuicem, propterea quod pendent omnes à corde; mouet autem ſemper, quare & illa ſemper, & ſimul inuicem quando mouet.* 3. Anim. cap. 9. De reſpir. cap. 15.

Notandum cum Galeno, à veteribus Philoſophis venas pro arteriis, appellatas fuiſſe. Accidit aliquando me vidiſſe, & præ manibus habuiſſe caſum quendam, qui mihi hanc veritatem apertiſſime confirmabat. Habuit quidam tumorem ingentem pulſantem Aneutiſma dictum in dextra parte juguli prope deſcenſum arteriæ ſubclauiæ in axillas ab ipſius arteriæ exeſione prognatum (qui ſummum in dies incrementum capeſſebat) & illud propter miſſionem ſanguinis ab arteria, ſingulis pulſationibus diſtentis (quod ſecto poſt mortem cadauere) deprehenſum erat) in illo pulſus eiuſdem brachii exilis admodum, eo quod maior ſanguinis portio, & influxus in tumorem diuertebatur, & interceptus fuit.

Quare ſiue per compreſſionem, ſiue per infarctum, vel interceptionem vbicunque ſanguinis motus per arterias prçpeditur, ibi vlteriores arteriæ minus pulſant, cum pulſus arteriarum, nil niſi impulſus ſit ſanguinis in arterias.

CAPVT IV.

Motus cordis & auricularum qualis ex viuorum diſſectione.

PRæter hæc circa motum cordis obſeruanda ſunt, quæ ad auricularum vſum ſpectant.

Quod Caſpar Bauhinus & Iohannes Riolanus viri doctiſſimi, &

aubin. b.2.c.11. Anatomici peritiſſimi obſeruarũt & admonent, quod ſi in viua fectio
ban.Rio- ne alicuius animalis cordis motum ſtudioſe obſerues, quatuor motus
n. lib. 8. loco,& tempore diſtinctos aſpicies: quorum duo ſunt proprii auricu-
ap.1. larum,ventriculorum duo. Pace tantorum virorum,quatuor ſunt motus,loco,non vero tempore diſtincti. Simul enim ambæ auriculæ mouent, & ſimul ambo ventriculi, vt quatuor loco motus diſtincti ſint duobus tantum temporibus,atque hoc ſe habet modo.

Duo ſunt quaſi eodem tempore motus, vnus auricularum, alteriptorum ventriculorũ:nec enim ſimul omnino fiunt: ſed præcedit motus auricularum,& ſubſequitur cordis, & motus ab auriculis incipere, & in ventriculos progredi viſus eſt.cum iam languidiora omnia emoriente corde, & in piſcibus, & in frigidioribus ſanguineis animalibus inter hos duos motus, tempus aliquod quietis intercedit, vt cor quaſi ſuſcitatum motui reſpondere videtur,aliquando citius,aliquando tardius, & tandem ad mortem inclinans ceſſat motu ſuo reſpondere, & quaſi capite duntaxat leuiter annuit,& obſcure adeo mouetur, vt potius motus ſignum præbere pulſanti auriculæ videatur. Sic prius deſinit cor pulſare, quam auriculæ, vt auriculæ ſuperuiuere dicantur, & primus omnium definit pulſare ſiniſter ventriculus, deinde eius auricula, demum dexter ventriculus,vltimo (quod etiam notauit Galen.) reliquis omnibus ceſſantibus,& mortuis pulſat vſque dextra auricula, vti vltimo in dextra auricula vita remanere videatur. Et dum ſenſim emoritur cor videre licet, poſt duas vel tres pulſationes auricularum. liquando quaſi expergefactum correſpondere,& vnum pulſum lente, & ægrè peragere,& moliri.

Sed & præcipue notandum, quod poſtquam ceſſauit cor pulſare adhuc auricula pulſante digito ſuper ventriculum cordis poſito, ſingulæ pulſationes percipiuntur in ventriculis, eodem plane modo, quo ventriculorum pulſationes in arteriis ſentiri antea diximus,à ſanguinis impulſu nimirum diſtẽtione facta,& hoc tempore,pulſante ſolum auricula,ſi forfice cordis mucronem abſecueris, exinde ſingulis auriculæ pulſationibus ſanguinem effluere conſpicies:vt hinc pateat quomodo in ventriculos ſanguis ingrediatur, non attractiõne, aut diſtentione cordis,ſed ex pulſu auricularum immiſſus.

Notandum eſt vbique omnes,quas voco,& in auriculis, & in corde pulſationes, contractiones eſſe: & plane primo contrahi auriculas videbis,& in conſequentia,cor ipſum. Auriculæ enim dum mouentur,&

pulſant

pulſant albidiores fiunt, præſertim vbi pauco ſanguine replentur (replentur autem tanquam promptuarium, & lacuna ſanguinis, declinante ſponte ſanguine, & venarum motu compreſſo ad centrum) quin etiam in finibus, & extremitatibus ipſarum hæc albedo à contractione fieri, vel maxime apparet.

In piſcibus, & ranis, & ſimilibus (vnum ventriculum habent cordis & pro auricula veſicam quandam in baſi cordis poſitam refertiſſimam ſanguine) hanc videbis veſicam primo contrahi, & ſubſequi poſtea cordis contractionem apertiſſime.

At vero & quæ his contrario modo ſe habent à me obſeruata aſcribere huc viſum eſt. Cor anguillæ, & quorundam piſcium, & animaliũ etiam exemptum ſine auriculis pulſat: Immo ſi in fruſta diſſecueris partes eius diuiſas ſeparatim ſeſe contrahere, & laxare videbis ita, vt in his poſt ceſſationem motus auricularum cordis corpus pulſum faciat, & palpitet. Sed an hoc proprium viuacioribus animalibus, quorum radicale humidum glutinoſum magis, aut pingue, & lentum eſt, & non ita facile diſſolubile. Quod etiam apparet in carne anguillarum, quæ poſt excoriationem, exenterationem, & in fruſta diſſectionem motum retinet.

In Columba certe experimento facto poſtquam cor deſierat omnino moueri, & nunc etiam auriculæ motum reliquerant per aliquod ſpacium digitum ſaliua madefactum, & calidum cordi ſuperimpoſitũ detinui: Quo fomento quaſi vires, & vitam poſtliminio recuperaſſet, cor, & eius auricula moueri, & ſeſe contrahere, atque laxare, & quaſi ab orco reuocari videbantur.

Sed & præter hæc aliquoties à me obſeruatum fuit, poſtquam cor ipſum, & eius auricula etiam dextra, à pulſatione quaſi mortis articulo quieſcebant; in ipſo ſanguine qui in dextra auricula continetur, obſcurum motum, & inundationem, ac palpitationem quandam manifeſto ſuperfuiſſe, tamdiu ſcilicet, qua calore & ſpiritu imbui videretur.

Tale quiddam euidentiſſime in prima animalis generatione intra ſeptem dies ab incubatione, in ouo Gallinaceo cernitur. Ineſt primum ante omnia gutta ſanguinis, quæ palpitat (quod etiam annotauit Ariſtot.) ex qua incremento facto, & pullo aliqua ex parte formato, fiunt cordis auriculæ, quibus pulſantibus perpetuo ineſt vita: cum poſtea corpus delineari intermiſſis aliquot diebus inceperit, tum etiam cordis corpus procreatur, & per aliquod tempus albidum apparet, & ex-

angue, vt reliquum corpus, nec pulsum edit, nec motum. Quin etiam in fœtu humano vidi, circa principium tertii mensis similiter cor formatum, sed albidum, & exangue, cuius tamen auriculis sanguis inerat vberrimus & purpureus. Sed enim in ouo, iam adaucto, & couformato fœtu, simul, & cor adaugeri, & ventriculos habere, quibus sanguinem tunc recipere, & transmittere occepit.

Ita vt si penitius introspicere quis velit, non solum cor esse primum viuens, & vltimum moriens dixerit, sed auriculas (& quæ in serpentibus, piscibus, & huiusmodi animalibus pars pro auricula est) & prius quam cor ipsum viuere, & post etiam emori.

Imo an prius adhuc ipse sanguis, vel spiritus habeat in se obscuram palpitationem quam post mortem retinere mihi visus est: & an cum palpitatione vitam incipere dicamus, dubitare contingit, quandoquidem, & sperma animalium omnium (vt notauit Arist.) & spiritus prolificus palpitando exit, velut animal quoddam. Ita Natura in morte quasi decursione facta reducem (vt Arist.) agat motu retrogrado à calce ad carceres eo vnde prouit se se recipit, & cum animalis generatio ex non animali procedat in animal, tanquam ex non ente in ens iisdem retro gradibus corruptio ex ente reuoluatur in non ens, vnde quod in animalibus vltimo fit deficit primum & quod primo vltimum.

De motu animaliū cap. 8.

Obseruaui quoque in omnibus pene animalibus cor vere inesse, & non solum (vt Aristot. dicit) in maioribus, & sanguineis, sed in minoribus, exanguibus, crustatis, & testaceis quibusdam, vt lumacibus, cochleis, conchis, astacis, gammaris, squillis, multisque aliis; imo vespis, & crabronibus muscis (ope perspicilli ad res minimas discernendas) in summitate illius particulæ quæ cauda dicitur, & vidi pulsans cor, & aliis videndum exhibui.

In exanguibus vero Corlente admodum, rarisque ictibus pulsat, atque vt in aliis iam moribundis contingit, & tarde sese contrahit, vt facile in cochleis est cernere. Quorum cor deprehendes in fundo illius orificii in latere dextro quod se aperire, & claudere euentionis causa videtur, & vnde saliuam expuit, sectione facta in summitatem iuxta partem iecori analogam.

Sed notandum & hoc, hyeme, & frigidioribus tempestatibus exanguia aliqua (qualis est Cochlea) nihil pulsans habent, sed vitam magis plantæ agere videntur, vt etiam reliqua quæ plant- animalia ideo dicuntur.

Notan-

Notandum insuper in omnibus animalibus vbi cor ineſt, ibi etiam auriculas eſſe vel auriculis aliquid analogon: Et vbicunque cor duplici ventriculo donatur, ibi duas ſemper adſtare auriculas, non contra: Sed ſi in ouo pulli conformationem aduertas: Primum ineſt vt dixi, tantum veſicula, vel auricula, vel gutta ſanguinis pulſans, poſtea incremento facto abſoluitur cor. Ita quibuſdam animalibus (quaſi vlteriorem perfectionem non adipiſcentibus) pulſans veſicula quædam inſtar puncti cuiuſdam rubri vel albi, duntaxat ineſt, quaſi principium vitæ: vti apibus, veſpis, cochleis, ſquillis, Gammaris, &c.

Eſt hic apud nos minima ſquilla (quæ Anglicè dicitur a Shrimp, Belgice een Herneel) in mari, & in Thameſi capi ſolita, cuius corpus omnino pellucidum eſt: Eam aquæ impoſitam ſæpius præbui ſpectandam amiciſſimis quibuſdam meis, vt cordis illius animalculi motus liquidiſſime perſpiceremus, dum exteriores illius corporis partes viſui nihil officerent, quo minus cordis palpitationem quaſi per feneſtram intueremur.

In ovo Gallinaceo poſt quatuor, vel quinque dies ab incubatione, primum rudimentum pulli inſtar nubeculæ videndum exhibui, nimirum ouo cui cortex adimebatur, in aquam limpidam, tepidamque immiſſo, in cuius nubeculæ medio punctum ſanguineum palpitans tam exiguum erat, vt in contractione diſpareret, & viſum aufugeret in laxatione inſtar ſummitatis acus appareret rubicundum: Ita vt interipſum videri, & non videri quaſi intereſſe & non eſſe, palpitationem & vitæ principium ageret.

CAPVT V.

Cordis motus actio, & functio.

EGo vero ex his tandem, & huiuſmodi obſeruationibus repertum iri confido, motum cordis ad hunc modum fieri.

Primum ſeſe contrahit auricula. & in illa contractione ſanguinem contentum (quo abundat tanquam venarum caput, & ſanguinis prōptuarium, & ciſterna) in ventriculum cordis coniicit, quo repleto cor ſeſe erigit, continuo omnes neruos tendit, contrahit ventriculos, & pulſum facit, quo pulſu immiſſum ab auricula ſanguinem continenter protrudit in arterias, dexter ventriculus in pulmones per vas illud,

quod vena arteriosa nominatur, sed re vera, & constitutione, & officio, & in omnibus atteria est: sinister ventriculus in aortam, & per arterias in vniuersum corpus.

Isti duo motus, auricularum vnus, alter ventriculorum ita per consecutionem fiunt, seruata quasi harmonia & Rhytmo, vt ambo simul fiant, vnicus tantum motus appareat, præsertim in calidioribus animalibus, dum illa celeri agitantur motu. Nec alia ratione id fit quam cum in machinis, vna rota aliam mouente, omnes simul mouere videantur, & in mechanico illo artificio, quod sclopetis adaptant, vbi compressione alicuius ligulæ, cadit silex, percutit chalybem, & propellit, ignis elicitur, qui in puluerem cadit, ignitur puluis, interius prorepit, disploditur, euolat globulus, metam penetrat, & omnes isti motus propter celeritatem quasi in nictu oculi simul fieri apparent. Sic etiam in deglutitione radicis, linguæ eleuatione, & oris compressione, cibus vel potus in fauces deturbatur, larinx à musculis suis, & epiglottide clauditur, eleuatur, & aperitur, summitas gulæ à musculis suis, haud aliter quam saccus ad implendum attollitur, & ad recipiendum dilatatur, & cibum, vel potum acceptum transuersis musculis deprimit, & longioribus attrahit: Et tamen omnes isti motus à diuersis, & contradistinctis organis facti, cum harmonia, & ordine, dum fiunt, vnum efficere motum videntur, & actionem vnam, quam deglutitionem vocamus.

Sic contingit plane in motione, & actione Cordis, quæ deglutitio quædam est, & transfusio sanguinis è venis in arterias: Et si quis (dum hæc habuerit in animo) cordis motum diligenter in viua dissectione animaduerterit, videbit, non solum, quod dixi, cor sese erigere, & motum vnum fieri cum auriculis continuum, sed inundationem quandã, & lateralem inclinationem obscuram secundum ductum ventriculi dextri, & quasi sese leuiter contorquere, & hoc opus peragere: Et quemadmodum cernere licet, cum equus potat, & aquam deglutit, singulis gulæ tractibus absorberi aquam, & in ventriculum demitti, qui motus sonitum facit & pulsum quendam & auscultantibus, & tãgentibus exhibet, ita dum istis cordis motibus fit portionis sanguinis è venis in arterias traductio, pulsum fieri, & exaudiri in pectore contingit.

Motus itaq; cordis omnino ad hunc se habet modum, & vna actio cordis est ipsa sanguinis transfusio, & in extrema vsq;, mediantibus arteriis propulsio, vt pulsum; quem nos sentimus in arteriis, nil nisi sanguinis à corde impulsus sit. An vero

An vero cor ſanguini præter tranſpoſitionem, & motum localem, & diſtributionem aliquid aliud addat, ſiue calorem, ſiue ſpiritum, ſiue perfectionem, poſterius inquirendum, & ex aliis obſeruationibus colligendum: Hoc in præſentia ſufficiat ſatis oſtenſum eſſe in pulſu cordis ſanguinem transfundi, & deduci è venis in arterias per cordis ventriculos, & diſtribui in vniuerſum corpus.

Sed & hoc omnes aliquo modo concedunt, & ex cordis fabrica, & valuularum artificio, poſitione, & vſu colligunt. Verum tanquam in loco obſcuro titubantes cœcutire videntur, & varia, ſubcontraria, & non cohærentia componunt, & ex coniectura plurima pronunciant, vt ante demonſtratum eſt.

Cauſa maxima hac in parte hæſitandi, & errandi vna fuiſſe mihi videtur, cordis cum pulmone in homine contextus: cum venam ibi arterioſam in pulmones obliterari, & ſimiliter arteriam venoſam conſpexiſſet, vnde aut quomodo dexter ventriculus in corpus diſtribueret ſanguinem: aut ſiniſter è vena caua exhauriret, obſcurum admodum illis erat; hoc atteſtantur Galeni verba (dum contra Eraſiſtratum de venarum origine & vſu, & ſanguinis coctione, inuehitur) *reſpondebitis* (inquit) *ita eſſe effectum, vt in iecore ſanguis præparetur, atque inde in cor deferatur, ibi poſtea reliquam propriæ formæ perfectionem abſolutam accepturus. Quod profecto ratione vacare non videtur: Nullum enim perfectum & magnum opus repente vna aggreſſione fieri, totamque ſuam expolitionem ab vno inſtrumento acquirere poteſt. Quod ſi ita eſt, oſtendite nobis vas aliud, quod è corde ſanguinem abſolute perfectum educat, atque ipſum vt arteria ſpiritum, in totum corpus diſpenſet.* Ecce opinionem rationabilem non approbaſſe, & reliquiſſe Galenum (quia præterquam quod viam tranſitus non videbat) vas reperire non poterat, quod in totum corpus è Corde ſanguinem diſpenſet. Galen. de placitis Hippoc. & Plat. &

Si quis vero ibidem pro Eraſiſtrato, vel pro illa, & nunc noſtra opinione (ipſius confeſſione Galeni) alias rationi conſentanea inſtaret, & arteriam magnam ſanguinem è corde in vniuerſum corpus diſpenſantem digito commonſtraſſet; Quid diuinus ille vir ingenioſiſſimus & doctiſſimus reſponderet, miror. Si arteriam ſpiritus diſpenſare & non ſanguinem diceret; profecto Eraſiſtratum refelleret ſatis (qui in arteriis ſpiritus duntaxat contineri arbitrabatur) ſed ſibi ipſi contradiceret interea & id eſſe turpiter negaret, quod

libro

lib o proprio acriter esse contendit, contra eundem Eristratum: & multis, & validis argumentis comprobat, & experimentis demonstrat, quod sanguis contineatur in arteriis natura, & non spiritus.

„ *Sin vero* diuinus vir (vti facit eodem loco sæpius) *concederet, omnes*
„ *arterias corporis à magna arteria oriri, & hanc à corde: quin etiam in ipsis o-*
„ *mnibus sanguinem natura contineri, & deferri, & valuulas illas tres sigmoides*
„ *orificio aortæ positas, regressum sanguinis in cor prohibere professus, & quod hæc*
„ *Natura nequaquam præstantissimo viscri constituisset, nisi maximum aliquod*
„ *ministerium illæ fuissent exhibituræ.* Si (inquam) hæc omnia, & his ipsissimis verbis concederet Pater Medicorum, (vti facit *recitato libro.*)

Quomodo negare possit arteriam magnam istiusmodi vas esse quod sanguinem (iam absolutam suam perfectionem adeptum) è corde in vniuersum corpus dispenset, non video. An adhuc forsan hæsitaret, vt omnes in hunc vsque diem post ipsum, quod propter contextum, vt dixi cordis cum pulmone, non videat vias, per quas sanguis è venis in arterias transferri possit.

Quod dubium etiam anatomicos (dum semper in dissectionibus inueniunt arteriam venosam, & sinistrum ventriculum cordis repletos sanguine, eoque crasso, grumescente, atro) non mediocriter perturbat cum sanguinem è dextro ventriculo in sinistrum per septum cordis transudare coacti sint affirmare. Sed hanc viam antea refutaui: Iam ideo via paranda est, & aperienda, qua inuenta, nunc nulla esset difficultas, quæ quempiam (credo) inhiberet, quo minus quæ ante proposui (de pulsu cordis, & arteriarum, de transfusione sanguinis è venis in arterias, & de dispensatione in vniuersum corpus per arterias) concedere, & agnoscere facile possit.

CAPVT VI.

Quibus viis sanguis, è vena Caua in arterias, vel e dextro ventriculo cordis in sinistrum deferatur.

CVm errandi occasionem præbuisse probabile sit, quam in homine vident (vt dixi) cordis cum pulmone connexionem: In hoc peccant, qui dum de partibus animalium (vti vulgo omnes Anatomici faciunt) pronunciare, & demonstrare, aut cognoscere volunt, vnum tantum hominem, eumque mortuum introspiciunt, & sic tanquam, qui

vna

vna reipub. forma perſpecta diſciplinam politicam componere, aut vnius agri naturam cognoſcentes, agriculturam ſe ſcire opinantur: Nihilo plus agunt, quam ſi ex vna particulari propoſitione, de vniuerſali Syllogizare darent operam.

Veruntamen, ſi in diſſectione animalium æque verſati eſſent, ac in humani cadaueris anatome exercitati: Res hæc in dubio, quæ omnes perplexos retinet, palam abſque omni difficultate mea ſententia eluceſceret.

In piſcibus, in quibus vnus tantum ventriculus cordis (vt non habentibus pulmones) res primum ſatis manifeſta eſt, veſicam enim ſanguinis in baſi Cordis poſitam, auriculæ nimirum analogon, ſanguinem in cor immittere, quem cor denuo per fiſtulam ſiue arteriam, vel arteriæ analogon, aperte tranſmittere, tum viſu, tum ſecta arteria (exindo ſanguine ſingula pulſatione cordis proſiliente) oculis palam confirmari poſſe conſtat.

Idem etiam deinde in omnibus animalibus, in quibus vnus duntaxat ventriculus, vel quaſi vnus, non difficile eſt cernere, vt in bufone, rana, ſerpentibus, lacertis, quæ etſi pulmones aliquo modo habere dicuntur, vt qui vocem habent (de quorum pulmonum artificio admirando, & de cæteris eiuſmodi, | permultas apud me obſeruationes habeo quæ non ſunt huius loci) tamen ex autopſia eodem modo in illis è venis in arterias ſanguinem pulſu cordis traductum eſſe palam eſt, & via patens aperta, manifeſta, nulla difficultas, nullus hæſitandi locus: In his enim perinde ſe res habet atque in homine, ſi ſeptum cordis perforatum, aut ademptum eſſet, aut vnus ex vtriſque fieret ventriculus, quo facto, nemo credo dubitaſſet, qua via ſanguis è venis in arterias tranſire potuiſſet.

Cum vero maior numerus animalium non habentium pulmones ſit, quam habentium, & ſimiliter maior numerus ſit, vnum tantum ventriculum cordis, quam habentium duos, procliue eſt ſtatuere in animalibus ἐπὶ τὸ πολὺ vt plurimum, & in vniuerſum, ſanguinem aperta via è venis in arterias per cordis ſinum tranſmitti.

Conſideraui autem mecum, quod etiam in embryonum eorum quę pulmones habent, idem apertiſſime conſtat.

In fœtu vaſa cordis quatuor (videlicet vena caua, vena arterioſa, arteria venalis, & Aorta, ſiue arteria magna) alio modo vniuntur, quàm in adulto, quod omnes Anatomici norunt ſatis.

Primus contactus, & vnio venæ cauæ cum arteria venoſa (quæ fit priuſquam caua in dextrum ventriculum cordis ſe aperiat, aut venam coronalem emittat, paululum ſupra egreſſum ab hepate) Anaſtomoſim lateralem exhibet, hoc eſt, foramen amplum patens, ouali figura. peruſum è caua in arteriam illam peruium, ita vt (tanquam per vnum vas) per illud foramen ſanguis de vena caua in arteriam venoſam, & auriculam cordis ſiniſtram vſque in ventriculum ſiniſtrum liberrime, & copioſiſſime dimanare poſſit. Inſuper in illo foramine ouali è regione, quæ arteriam venoſam reſpicit, operculi inſtar membrana tenuis dura eſt, foramine maior, quæ poſtea in adultis, operiens hoc foramen, & coaleſcens vndique iſtud foramen omnino obſtruit, & prope obliterat: Hæc inquam membrana ſic conſtituta eſt, vt dum laxe in ſe concidit, facile ad pulmones, & cor via reſupinetur, & ſanguini à caua affluenti cedat quidem, at ne rurſus in canam refluat, impediat, vt liceat exiſtimare in embryone ſanguinem continuo debere per hoc foramen tranſire de vena caua in arteriam venoſam, & inde in auriculam ſiniſtram cordis, poſtquam ingreſſum fuerit, remeare nunquam poſſe.

Altera vnio eſt venæ arterioſæ (quæ fit poſtquam vena illa, è dextro ventriculo egreſſa in duos diuiditur ramos) eſt tanquam duobus dictis, tertius truncus, & quaſi canalis arterioſus; ab hinc in arteriam magnam obliquè ductus, & perforatus: vt in diſſectione Embryonum. quaſi duæ aortæ, vel radices arteriæ magnæ è corde exorientes duæ appareant.

Canalis hic in adultis ſimiliter ſenſim attenuatur, tabeſcit, & penitus tandem vt vena vmbilicalis exiccatur, & aboletur.

Iſte canalis arterioſus nullam membranam in ſe habet, ſanguinis motum hinc, vel illinc impedientem. Sunt enim in orificio illius venæ arterioſæ (cuius iſte canalis, vti dixi, propago eſt) valuulæ ſigmoides tres quæ intus foras ſpectant, & ſanguini è dextro ventriculo hac via in magnam arteriam fluenti cedunt facile, remeare veto contra ab arteria quidquam, aut à pulmonibus in dextrum ventriculum ad amuſſim clauſum omnino impediunt. Vt hic etiam arbitrari conſentaneum ſit in Embryone, dum cor ſeſe contrahit continuo ſanguinem è dextro ventriculo hac via in arteriam magnam inuehi.

Quod vulgo dicitur, has duas vniones tam magnas, patentes, & apertas,

apertas, nutriendorum pulmonum cauſa, factas fuiſſe tantum: & in adultis (cum iam pulmones propter ipſorum calorem, & motum copioſius nutrimentum deſiderarent) aboleri, & conſolidari; Commentum improbabile eſt, & male cohærens. Et ſimiliter quod dicunt cor in embryone feriari, & nihil agere, nec mouere, vnde Natura hos tranſitus facere, alendorum pulmonum cauſa coacta erat, falſum eſt: cum in ouo cui gallina incubuit, & in Embryonibus recenter ex vtero erectis autopſia patet, tum cor mouere ſicut in adultis tum naturam nulla tali neceſſitate vrgeri: Cui motui non ſo'um hi oculi ſæpe teſtes, ſed Lib. ſpir
& Ariſtoteles atteſtatur ipſe: *Pulſus (inquit) per initia ſtatim in conſtitu-*
tione cordis emergit, & quod in ſectione viuorum, & pulli formatione ex ouo de-
prehenditur. Quin & obſeruamus has vias (tam in hominum genere, quam in cæteris animalibus) non ſolum apertas, & patentes eſſe vſque ad tempus partus (vt annotarunt Anatomici) ſed etiam permultos poſt menſes, imo in aliquibus per aliquot annos, ne dicam toto vitæ curriculo, veluti in anſere, buccagine, & auibus plurimis, & animalibus præſertim in minoribus. Quæ res impoſuit forſan Botallo ſe nouum tranſitum ſanguini de vena caua in ſiniſtrum ventriculum cordis inueniſſe, & fateor, me quoque cum in mure maiori iam adulto hoc primum ipſe reperi, tale quid ſtatim exiſtimaſſe.

Ex quibus intelligitur in Embryone humano, quin, & in aliis, in quibus iſtæ vniones non abolentur, idem ipſum accidere, vt cor ſuc moru, per patentiſſimas vias ſanguinem de vena caua in arteriam magnam apertiſſime traducat, per vtriuſque ventriculi ductum. Dexter ſiquidem ſanguinem ab auricula recipiens, inde per venam arterioſam, & propaginem ſuam (canalem arterioſam dictam) in magnam arteriam propellit. Siniſter ſimiliter eodem tempore mediante auriculæ motu recipit ſanguinem (in illam ſiniſtram auriculam diductum ſcilicet per foramen ouale è vena caua) & tentione ſua, & conſtrictione per radicem aortæ in magnam itidem arteriam ſimul impellit.

Itaq; in Embryonibus dum interea pulmones otiantur, & nullam actionem aut motum habent, quaſi nulli forent, natura duobus ventriculis cordis quaſi vno vtitur, ad ſanguinem tranſmittendum. Et ſimilis eſt conditio Embryonum pulmones habentium, dum adhuc pulmonibus non vtuntur, ac eſt eorum animalium, qui pulmones non habent.

Itaque tam clare in his etiam eluceſcit veritas, quod cor ſuo pulſu ſanguinem è vena caua in arteriam magnam traducat, & transfundat, perque tam patentes, & aperras vias, ac ſi in homine, quod dixi ambo ventriculi (eorum ſepto adempto) adinuicem peruii eſſent facti. Cum itaque maiori ex parte animalibus, & omnibus quodam tempore, patentiſſimæ iſtæ extent viæ, quæ tranſmiſſioni ſanguinis per cor inſeruiunt: reſtat vt illud perquiramus. Aut cur in quibuſdam animalibus (vt in homine) iiſque calidioribus, & adultis per pulmonum ſubſtantiam illud fieri non exiſtimemus, quod in embryone natura per eas vias illo tempore quo pulmonum nullus erat vſus antea effecit, quas ob defectum tranſitus per pulmones coacta videbatur facere. Aut, cur melius ſit (natura enim ſemper quod eſt melius facit) in adoleſcentibus ſanguinis tranſitui naturam omnino occluſiſſe, vias patentes illas quibus ante in embryone & fœtu via fuerat, & omnibus aliis animalibus vtitur, nec alias vllas pro illo ſanguinis tranſitu aperuiſſe, ſed ſic omnino impedire.

Ita iam eo res ceſſit, vt iis qui in homine quærunt vias, quomodo ſanguis è vena caua in ſiniſtrum vẽtriculum, & arteriam venoſam permeat. Magis operæ pretium eſſet, & recte magis factum videretur, ſi ex diſſectione animalium veritatem inueſtigare vellent, vt cauſam inquirant, cur in maioribus, & perfectioribus animalibus, iiſque adultis natura ſanguinem tranſcolari per pulmonum Parenchyma potius velit, quam vt in cæteris omnibus per patentiſſimas vias (cum nullam aliam viam, & tranſitum excogitari poſſe intelligerent, ſiue hoc ſit quod maiora, & perfectiora animalia ſint calidiora, & cum ſint adulta, eorum calor magis (vt ita dicam) igniatur & vt ſuffocetur ſit procliuis: Ideo tranare, & traiici per pulmones, vt inſpirato aere contemperetur, & ab ebullitione, & ſuffocatione vindicetur, ſiue quid aliud tale. Sed hæc determinare, & rationem omnem reddere, nihil aliud agere eſt, quam propter quid pulmones facti ſunt, ſpeculari. Atque de his horumque vſu, & motu, & de cuentatione omni, & aeris neceſſitate, & vſu, & cæteris huiuſmodi: Et de variis organis, & differentibus huius cauſa in animalibus factis: tametſi multa quam plurimis obſeruationibus à me deprehenſa ſint: Tamen, ne nimium à propoſito de motu, & vſu cordis hoc loco aberrando, aliud agere, & ſtationem relinquere, rem interturbare, & ſubterfugere videar, hæc proprio tractatu conuenientius exponenda relinquam. Et quæ reſtant vt ad propoſitum ſcopum reuertar confirmare pergam.

In.

In perfectioribus nimirum & calidioribus animalibus, iiſque adultis (vt in homine) ſanguinem de dextro ventriculo cordis per venam arterioſam in pulmones, & inde per arteriam venoſam in ſiniſtram auriculam, & ſubinde in ventriculum cordis ſiniſtrum permeare contendo: Et primum poſſe hoc fieri, deinde ita factum eſſe.

CAPVT VII.

Sanguinem de dextro ventriculo cordis per pulmonum parenchyma permeare in arteriam venoſam, & ſiniſtrum ventriculum.

Fieri autem hoc poſſe, & nihil eſſe, quo minus fiat, ſatis conſtat, cum & quomodo aqua per terræ ſubſtantiam permeans, riuulos, & fontes procreet, conſideremus, aut quomodo per cutem ſudores: per parenchyma renum, vrina fluat, ſpeculamur. Animaduertendum eſt in iis, qui Aquis Spadenſibus vtuntur: vel de la Madonna (vt aiunt) in agro Patauino, vel aliis acidulis, aut vitriolatis, vel qui ad congios ingurgitant potum, vt vna aut altera hora per veſicam emingant totum. Debet iſta copia aliquantulum in concoctione immorari: debet per iecur (vt ſingulis diebus bis ingeſti alimenti ſuccum omnes confitentur facere) debet per venas, per renum parenchyma, per vreteres in veſicam profluere.

Quos itaque audio negantes poſſe ſanguinem, imo totam maſſam ſanguineam, per pulmonum ſubſtantiam, æque ac ſuccus alimentalis per iecur permeare, tanquam impoſſibile, & nullo modo credibile exiſtimandum? Quod genus hominum (cum Poeta loquor) vbi volunt concedunt facile poſſe: vbi nolunt nullo modo: hic vbi opus eſt verentur, vbi nihilo opus, ibi non verentur affirmare.

Iecoris Parenchyma denſius multo eſt, & ſimiliter renum: pulmonum rarioris multo texturæ. Et ſi renibus & iecori conferatur ſpongioſæ.

In iecore nullum impellens, nulla vis cogens; in pulmone ex pulſu dextri ventriculi cordis impingitur ſanguis, cuius impulſu diſtendi vaſa, & poroſitates pulmonum neceſſe eſt. Præterea pulmones in reſpirando eleuantur, & concidunt, quo motu neceſſe eſt, vt poroſitates; & vaſa aperiantur, & claudantur, vt in ſpongiis contingit, & in omnibus par- Gal. de vſ. part.

bus particulis habentibus conſtitutionem ſpongioſam, quando conſtringuntur, & rurſus dilatantur. Contra jecur quieſcit, nec ita dilatari, & conſtringi viſum eſt.

Denique ſi per jecur totum ingeſtorum ſuccum in venam cauam, tam in homine, quam in boue, vel in maximis animalibus, nemo eſt; qui non aſſerit pertranſire poſſe. Et hoc: eo quod pertranſiiſſe aliqua nutrimentum, & permeaſſe in venas ſit neceſſe (ſi fiat nutritio) & nulla alia extet via, ac proinde hoc affirmare coacti ſint: Cur non iiſdem argumentis de tranſitu ſanguinis in adultis his; per pulmones fidem ſimilem habent, & cum Columbo peritiſſimo, doctiſſimoque Anatomico idem aſſererent, & crederent, ex amplitudine, & fabrica vaſorum pulmonum, & eo, quod arteria venoſa, & ſimiliter ventriculus, repleti ſint ſemper ſanguine, quem è venis huc veniſſe neceſſe eſt, & nulla alia, quam per pulmones ſemita, vt & ille, & nos ex ante dictis, & autopſia, aliiſque argumentis palam eſſe exiſtimemus.

Sed quando aliqui ſunt, qui nil niſi adductis authoritatibus admittunt; iidem ex ipſius etiam Galeni verbis hanc veritatem confirmari poſſe ſciant; ſcilicet non ſolum poſſe ſanguinem, è vena arterioſa in arteriam venoſam, & inde in ſiniſtrum ventriculum cordis, & poſtea in arterias tranſmitti: ſed ex continuo pulſu cordis, & pulmonum motu inter reſpirandum, hoc fieri.

Sunt in orificio venæ arterioſæ, valuulæ tres ſigmoides, ſiue ſemilunares, quæ omnino ſanguinem in illam venam arterioſam immiſſum non ſinunt remeare in cor.

Id omnes norunt ſcilicet harum valuularum neceſſitatem & vſum,

Galen. de vſu part l. 6. c. 10. „Galenus his verbis explicans, *In toto eſt* (inquit) *mutua Anaſtomoſis, at-*
„*que oſcillorum apertio arteriis ſimul cum venis, tranſumuntque ex ſeſe pariter*
„*ſanguinem, & ſpiritum per inuiſibiles quaſdam atque anguſtas plane vias.*
„*Quod ſi os ipſum venæ arterioſæ itidem ſemper patuiſſet, nullamque natura in-*
„*ueniſſet machinam, qua claudere ipſum cum eſt tempeſtiuum, ac rurſus ape-*
„*rire queat. Fieri nunquam potuiſſet, vt per inuiſibilia, atque exigua oſcilla,*
„*ſanguis (contracto thorace) in arterias tranſumeretur: Neque enim ſimi-*
„*liter omnis ex quouis attrahitur, neque emittitur. Sed quemadmodum quod*
„*leue eſt facilius eo quod grauius dilatatis inſtrumentis attrahitur, iiſdem au-*
„*tem contractis exprimitur: Ita & per latam viam celerius aliquid quam per*
„*anguſtam trahitur, ac rurſus emittitur. Cum autem thorax contrahitur, pul-*
ſa atque

ſa atque intro compreſſæ vndique fortiter, quæ in pulmone ſunt venoſæ arteriæ, « *exprimunt quidem quam celerrime, qui in ſeipſis eſt, ſpiritus; tranſumunt au-* « *tem per ſubtilia illa oſcilla ſanguinis portionem aliquam, quod nunquam acci-* « *diſſet profecto, ſi ſanguis per maximum os (cuiuſmodi eſt vena arterioſa ad cor)* « *vetro remeare potuiſſet: Nunc vero reditu per os magnum intercluſo, dum com-* « *primitur vndique, deſtillat quidpiam in arterias per exigua illa orificia:* & pau- « lo poſt ſequente Capitulo. *Quanto thorax contendit vehementius ſan-* « *guinem elidens, tanto membranæ, (videlicet valuulæ ſigmoides) exactius os ipſum* « *occludunt: & nihil remeare ſinunt:* quod & eodem Capitulo decimo « paulo ante. *Niſi valuulæ eſſent, triplex ſequeretur incommodum, vt ſan-* « *guis ipſe fruſtra longum hoc curriculum ſubinde emetiatur. In Diaſtole quidem* « *pulmonis adfluens, & quæ in ipſo ſunt, venas omnes refarciens, in Syſtolis ve-* « *ro, quaſi æſtus quidam maritimus, inſtar Euripi motum idemtidem, huc* « *atque illuc reciprocum, qui haudquaquam ſanguini conueniat. At hoc vi-* « *deri poſſit exiguum. Quod vero interim ipſius quoque reſpirationis vtilita* « *tem labefactet, id non umplius pro paruo eſt habendum, &c.* (Et paulo « poſt.) *Atque etiam tertium ſecutum fuiſſet incommodum, haudquaquam* « *contemnendum, cum ſanguis retro in expirationibus remigraſſet, niſi opifex* « *noſter membranarum Epiphyſin fuiſſet fabricatus,* vnde concludit Cap. « vndecimo. *Communis autem ipſorum omnium, videlicet valuularum eſt* « *vſus, vt materias retro remigrare prohibeant, vtrarumqxe vero proprius, e-* « *ducentium quidem è corde materias, ne amplius ad ipſum remeent; inducentium* « *vero, ne amplius ex ipſo effluant: Non enim voleoat natura vano labore cor fati-* « *gari, neque in eam partem aliquando emittere, vnde trahere præſtitcrat, neque* « *rurſus ex illa identidem ducere, ad quam mittere erat neceſſe. Proinde cum ſint* « *quatuor omnino orificia, bina in vtroq; ventriculo, alterum quidem inducit, al-* « *terum vero educit.*

Et paullo poſt: *Porro exm vas alterum quod tunicæ ſimplici conſtat in cor* « *inſigatur, alterum quod duplice ex ipſo producatur communem vtrique locum,* « [*videlicet ventriculum dextrum*: Ira Galenus intelligit, & ego eadem ratio- ne ſimiliter ſiniſtrum ventriculum cordis] *quaſi lacunam quandam pa-* « *rari neceſſe fuit, ad quam pertinentibus vtriſque per alterum quidem trahatur* « *ſanguis per reliquum vero emittatur.*

Quod argumentum Galenus pro tranſitu ſanguinis per dexcrum ventriculum de vena caua in pulmones adducit, eodem nobis, rectius pro tranſitu ſanguinis de venis per cor in arterias mutatis tantum terminis vti liceat. Ex Galeni igitur viti diuini patris Medico-

Medicorum locis & verbis clare apparet, & ſanguinem per pulmones de vena arterioſa, in arteriæ venoſæ ramulos permeare, tum propter pulſum cordis, tum propter pulmonum & thoracis motum. Quinetiam quod cor continue in ventriculos quaſi lacunam, recipere & emittere ſanguinem, & huius rei cauſa valuularum genera quatuor, duo inductioni, em ſſioni ſanguinis duo inſeruire; ne aut ſanguis Euripi in morem inconuenienter agitetur, huc, illuc, aut retro remearet, vnde trahere præſtiterat. & ex illa reflueret parte, ad quam mittere erat neceſſe. Et ſic cor vano labore fatigaretur, & pulmonum reſpiratio præpediretur, Denique clare apparet aſſertio noſtra, continue, & continenter ſanguinem per pulmonum poroſitates permeare de dextro in ventriculum ſiniſtrum, de vena cava in arteriam magnam: Nam cum continuo de dextro ventriculo immittatur ſanguis in pulmones per venam arterioſam, & ſimiliter continue è pulmonibus in ſiniſtrum attrahitur (quod ex dictis, & valuularum poſitione patet) quin pertranſeat continue fieri non poteſt.

Vide Hofmanni doctiſſimi Commentarium ſupra Galeni lib. 6. de vſu part. Quem librum poſt quam hæc à me ſcripta eſſent vidi.

Et itidem cum ſemper & continue ingrediatur ſanguis in cordis ventriculum dextrum, & egrediatur continue è ſiniſtro (quod ſimiliter, & ratione & ſenſu patet) quin continuo pertranſeat ſanguis de vena cava in Aortam impoſſibile eſt.

Illud igitur quod in animalibus maiori ex parte, & plane omnibus donec adoleſcant, per patentiſſimas fieri vias, ex diſſectione manifeſtum eſt, in adultis his per pulmonum cæcas poroſitates, & vaforum eius oſcilla, tam ex Galeni verbis, quam ex ante dictis illud inquam fieri æque manifeſtum eſt. Vnde apparet quod quanquam vnus ventriculus cordis videlicet ſiniſter ſufficiens eſſet ſanguinis diſpenſationi per corpus, & eductioni è vena caua, quemadmodum etiam fit in omnibus quæ pulmonibus carent, natura tamen cum voluerit ſanguinem ipſum per pulmones tranſcolari, dextrum ventriculum ſuperaddere coacta fuit, cuius pulſu per ipſos pulmones è vena caua in ſiniſtri ventriculi locum ſanguis compelleretur. Et hoc modo dextrum ventriculum pulmonum cauſa, & ob translationem ſanguinis, non ob nutritionem duntaxat dicendum: Quandoquidem tanto pluuentu annonæ, atque compulſu ſubminiſtrato, & tanto puriori, & ſpiritu oſiori (vtpote immediate à ventriculis cordis ſubuecto) indigere alimento pulmones magis, quam aut cerebri puriſſima ſubſtantia, aut oculorum ſplendidiſſima, & diuina conſtitutio, aut ipſius cordis caro, (quæ rectius per arteriam coronalē nutritur) inconueniens omnino eſt exiſtimare. Ca-

CAPVT VIII.

De copia ſanguinis tranſeuntis per cor è venis in arterias, & de circulari motu ſanguinis.

HVc vſque de transfuſione ſanguinis è venis in arterias, & de viis, per quas per transeat, & quomodo ex pulſu cordis, tranſmittatur diſpenſetur de quibus, forſan ſunt aliqui, qui, antea aut Galeni authoritate, aut Columbi, aliorumue rationibus adductis, aſſentiri ſe dicant mihi; nunc vero, de copia & prouentu iſtius per tranſeuntis ſanguinis, quæ reſtant, (licet valde digna conſideratu) cum dixero; adeo noua ſunt, & inaudita, vt non ſolum ex inuidia quorundam, metuam malum mihi, ſed verear, ne habeam inimicos omnes homines tantum conſuetudo, aut ſemel imbibita doctrina, altiſque defixa radicibus, quaſi altera natura, apud omnes valet, & antiquitatis veneranda ſuſpicio cogit. Vtcumque iam iacta eſt alea, ſpes mea in amore veritatis, & doctorum animorum candore: Sane cum copia quanta fuerat, tam ex viuorum, experimenti cauſa, diſſectione, & arteriarum apertione, diſquiſitione multimoda; tum ex ventriculorum cordis, & vaſorum ingredientium & egredientium Symmetria, & magnitudine, (cum natura nihil faciés fruſtra, tantam magnitudinem, proportionabiliter his vaſibus fruſtra non tribuerit) tum ex concinno & diligenti valuularum & fibrarum artificio, reliquaque cordis fabrica, tum ex aliis multis ſæpius mecum & ſerio conſideraſſem, & animo diutius euoluiſſem: quanta ſcilicet eſſet copia tranſmiſſi ſanguinis, quam breui tempore ea trãſmiſſio fieret, nec ſuppeditare ingeſti alimẽti ſuccum potuiſſe animaduerterim; quin venas inanitas, omnino exhauſtas, & arterias, ex altera parte, nimia ſanguinis intruſione, diſruptas, haberemus, niſi ſanguis aliquo ex arteriis denuo in venas remearet, & ad cordis dextrum ventriculum regrederetur.

Cœpi egomet mẽcum cogitare, an motionem quandam quaſi in circulo haberet, quam poſtea veram eſſe reperi, & ſanguinem è cordo per arterias in habitum corporis, & omnes partes protrudi, & impelli, à ſiniſtri cordis ventriculi pulſu, quemadmodum in pulmones per venam arterioſam à dextris; & rurſus per venas in venam cauam, & vſque ad auriculam dextram remeari, quemadmodum ex pulmonibus

per arteriam dictam venosam, ad sinistrum ventriculum vt ante dictum est.

Quem motum circularem, eo pacto nominare liceat, quo Aristoteles aerem & pluuiam circulare superiorũ motum æmulatus est. Terra enim madida à sole calefacta euaporat, vapores sursum elati condensant, condensati in pluuias rursum descendunt, terram madefaciunt & hoc pacto fiunt hic generationes & similiter tempestatum & meteororum ortus, a solis circulari motu, accessu, & recessu.

Sic verisimiliter cõtingat in corpore, motu sanguinis, partes omnes sanguine calidiori perfecto, vaporoso, spirituoso, (& vt ita dicam) alimentatiuo, nutriri, foueri, vegetari: Contra in partibus sanguinem refrigerari, coagulari, & quasi effatum reddi, vnde ad principium, videlicet, Cor; tanquam ad fontem siue ad lares corporis, perfectionis recuperandæ causa, reuertitur: ibi calore naturali, potenti, feruido, tanquam vitæ thesauro, denuo colliquatur, spiritibus, & (vt ita dicam) balsamo prægnans, inde rursus dispensatur, & hæc omnia à motu & pulsu cordis dependere.

Ita cor principium vitæ & sol Microcosmi (vt proportionabiliter sol Cor mundi appellari meretur) cuius virtute, & pulsus sanguis mouetur, perficitur, vegetatur, & à corruptione & grumefactione vindicatur: suumque officium nutriendo, fouendo, vegetando, toti corpori præstat. Lar iste familiaris, fundamentum vitæ author omnium; sed de his conuenientius, cum de huiusmodi motus causa finali speculabimur.

Hinc cum venæ sint viæ quædam, & vasa deferentia sanguinem; duplex est genus ipsarum, caua, & Aorta, non ratione lateris (vt Aristoteles) sed officio; & non (vt vulgo constitutione (cum in multis animalibus (vt dixi) in tunicæ crassitie, vena ab arteria non differat) sed munere & vsu distincta, vena & arteria ambæ à veteribus venæ non immerito dictæ (vt Galenus annotauit) eo quod hæc, videlicet arteria, vas est differens sanguinem, è corde in habitum corporis; illa sanguinem ab habitu rursus in cor; hæc via à corde, ad cor vsque illa; illa continet sanguinem crudiorem, effœtum nutritioni iam redditum inidoneum, hæc coctum, perfectum, alimentiuum.

CAPVT

CAPVT IX.

Eſſe ſanguinis circuitum ex primo ſuppoſito confirmato.

SEd ne verba dare nos dicat quiſpiam, & aſſertiones ſpecioſas tantum facere ſine fundamento, & non iuſta de cauſa innouare: tria cõfirmanda veniunt, quibus poſitis, neceſſario hanc ſequi veritatem, & rem palam eſſe arbitror.

Primum continue & continenter, ſanguinem è vena cana in arterias, in tanta copia, tranſmitti, pulſu cordis, vt ab aſſumptis ſuppeditari non poſſit, & adeo vt tota maſſa breui tempore illinc pertranſeat.

Secundum continue æquabiliter & continéter ſanguinem in quodcunque membrum & partem pulſu arteriarum impelli, & ingredi, maiori copia multo, quam nutritioni ſufficiens ſit, vel tota maſſa ſuppeditati poſſit.

Et ſimiliter tertio ab vnoquoque membro, ipſas venas, hunc ſanguinem perpetuo retroducere ad cordis locum.

His poſitis ſanguinem circumire, reuolui, propelli & remeare, à corde in extremitates, & inde in cor rurſus, & ſic quaſi circularem motum peragere, manifeſtum puto fore.

Supponamus (vel cogitatione, vel experimento) quantum ſanguinis, ſiniſter ventriculus in dilatatione (quum repletus ſit) contineat ſiue ℥ij. ſiue ℥iij. ſiue ℥j. ℈. ego in mortuo reperi vltra, ℥ij.

Supponamus ſimiliter, quanto minus in ipſa contractione, vel quãtum ſeſe contrahat cor, & quanto minorem ventriculus capacitatem habeat in ipſa contractione, vel ipſis contractionibus, quantum ſanguinis in arteriam magnam protrudat: (protrudere enim aliquid ſemper & ante demonſtratum eſt cap. 3. & omnes in Syſtole fatentur, ex fabrica valuularum perſuaſi) & veriſimili coniectura ponere liceat, in arteriam immitti partem vel quartam vel quintam vel ſextam, & minimum octauam.

Ita in homine, protrudi ſingulis cordis pulſibus ſupponamus vnciã ſemis, vel drachmas tres vel drachmam vnam ſanguinis, quæ propter impedimentum valuularum in cor remeare non poteſt.

Cor vna ſemihora pluſquam mille pulſus facit imo in aliquibus, & aliquando bis, ter, vel quater mille. Iam multiplicatis drachmis,

videbis vna ſemihora aut millies drachmas tres, vel drachmas duas, vel vncias quinquies centum, aut talem aliquam proportionatam quantitatem ſanguinis, per cor in arterias transfuſam, maiori ſemper copia quam in vniuerſo corpore contingat reperiri. Similiter in oue, aut cane per tranſit eſto ſcrupulum vnum, in vna cordis contractione, tum vna ſemihora mille ſcrupulos vel circa libras tres & ſemis ſanguinis, in quo corpore plerumque non continetur plus quatuor libris ſanguinis, hoc in oue experrus ſum.

Ita pene, ſupputatione facta ſecundum quod nimium coniectare poſſimus tranſmiſſi ſanguinis, & enumeratis pulſationibus, videatur omnem maſſæ quantitatem ſanguineæ per tranſire de venis in arterias per cor, & ſimiliter per pulmones.

Sed eſto, quod non vna ſemihora, ſed vna hora, vel vna die, vtcumq; manifeſtum facit plus ſanguinis per cor eius pulſu tranſmitti continue, quam vel ingeſtum alimentum poſſit ſuppeditare, vel in venis ſimul contineri.

Nec eſt dicendum, quod cor in ſua contractione aliquando protrudat, aliquando non, vel quaſi nihil, & imaginarium quid. hoc enim ante confirmatum eſt & præterea ſenſui contrarium eſt & rationi. Si enim dilatato corde repleri neceſſe ventriculos ſanguine, contracto neceſſe protrudere ſemper & non parum, cum & ductus non parui & contractio non pauca ſit: in quauis proportione videlicet: Subtripla, ſubſextupla, vel ſuboctupla ſimiliter proportio ſanguinis excluſi, debet eſſe ad ante contentum, & in dilatatione replentem; vti ſe habet capacitas contracti ventriculi ad illam, quæ eſt dilatati. Et eum in dilatatione non contingit repleri nihilo, vel imaginario. Ita in contractione nũquam nihil, vel imaginarium expellit, ſed ſemper aliquid ſecundum proportionem contractionis. Quare concludendum, ſi vno pulſu in homine, vel oue, vel boue, cor emittit drachmam vnam, & mille ſunt pulſus in vna ſemihora, contingit eodem tempore, libras decem & vncias quinque tranſmiſſas eſſe. Si vno pulſu drachmas duas lib. 20. & ℥. 10. Si ſemivnciam lib. 41. & ℥. 8. Si vnciam lib. 83. ℥. 4. contingit in vna ſemihora tranſfuſas (in quam) eſſe de vnis in arteriis.

Sed quantum in vnoquoque protrudatur ſingulis pulſationibus, & quando plus, & quando minus, & qua de cauſa, accuratius poſt hæc ex multis obſeruationibus à me forſan palam fiet.

Interim hoc ſcio, & omnes admonitos velim, quod aliquando vberiori

riori copia pertranſit ſanguis, aliquando minore, & ſanguinis circuitus quandoque citius, quandoque tardius peragitur, ſecundum temperamentum, ætatem, cauſas externas & internas, & res naturales, & non naturales, ſomnum, quietem, victum, exercitia, animi pathemata, & ſimilia.

Verum enimuero cum per pulmones & cor, vel minima copia trāſeat ſanguis, longe vberiori prouentu in arterias, & totum corpus deducitur quam ab alimentorum ingeſtione ſuppeditari poſſibile ſit, aut omnino, niſi regreſſu per circuitum facto.

Hoc etiam palam ſit ſenſu, viuorum diſſectionem intuentibus, non ſolum aperta magna arteria, ſed (quod confirmat Galen. in ipſo homine) ſi quæuis vel minima arteria diſſecta fuerit, vnius pene ſemihoræ ſpatio totam ſanguinis maſſam, & toto corpore, tam venis quam arteriis exhauſtam fore.

Similiter Lani oues, omnibus hoc ſatis atteſtari poſſunt quando teſciſſis arteriis iugularibus, in mactando boue; vnius horæ quad ante minus, totam ſanguinis maſſam exhauriunt, & vaſa omnia inanita reddunt in membrorum exciſſione & tumorum; ex larga ſanguinis profuſione, itidem comperimus aliquando breui contingere.

Nec perſtringit huius argumenti vim, quod per venas effluere in iugulatione, & in membrorum exciſione, æque, ſi non magis quam per arterias dicat quiſpiam, cum contra ſe res habet: venæ enim quia ſubſidunt, quia in ipſis nulla vis cogens foras ſanguinem, & quia impedimento valuularum poſitio eſt (vt poſtea patebit) parum admodum redunt. arteriæ vero impetu impulſum ſanguinem foras, largius, impetuoſius, tanquam cum Syphone eiectum profundunt: ſed experiunda res eſt, omiſſa vena & inciſa iugulari in oue, vel cane; & quanto impetu, quanta protruſione, quam cito omnem ſanguinem è toto corpore, tam venis, quam arteriis contingit inanire admirabile videbitur. Arterias autem nullibi ſanguinem è venis recipere, niſi tranſmiſſione facta per cor ex ante dictis patet; ſed ligando Aortam ad radicem cordis, & aperiendo iugularem, vel aliam arteriam ſi ſolum arterias inanitas, & venas repletas conſpexeris. non contingit dubitare.

Hinc cauſam aperte videbis, cur in Anatome, tantum ſanguinis reperiatur in venis, parum vero in arteriis, cur multum in dextro ventriculo, parum in ſiniſtro (quæ res antiquis dubitandi occaſionem forſan præbuit, & exiſtimandi, ſpiritus ſolos in illis concauitatibus contineri

dum vita ſuperſtes animal fuerat) cauſa forſan eſt quod de venis in arteriis nullibi datur tranſitus, niſi per cor ipſum, & per pulmones. Cum autem expirauerint, & pulmones moueri deſinant, de venæ arterioſæ ramulis, in arteriam venoſam, & inde in ſiniſtrum ventriculum cordis ſanguis permeare prohibetur (vt in Embryone ante notatum eſt, prohibitum fuiſſe ob defectum motus pulmonum, oſcilla & poroſitates cæcas, & inuiſibiles aperientium claudentium) cum vero vna cum pulmonibus cor non deſinat moueri, ſed poſtea pulſare: & ſuperuiuere pergat: contingit ſiniſtrum ventriculum, & arterias emittere in venas ad habitum corporis ſanguinem, & per pulmones non recipere, & proinde quaſi inanitas eſſe.

Sed hoc etiam in rem noſtram non parum facit fidei, cum huius nulla alia cauſa (niſi quam nos ex noſtra ſuppoſitione afferimus) adduci poſſit.

Præterea hinc patet, quo magis, aut vehementius arteriæ pulſant, eo citius in omni ſanguinis hæmorrhagia inanitum iri corpus.

Hinc etiam in omni Lipothymia, omni timore, & huiuſmodi, quãdo cor languidius & infirmius, nullo impetu pulſat, omnem contingit hæmorrhagiam ſedari & cohiberi.

Hinc etiam eſt, quod corpore mortuo, poſtquam cor ceſſauit pulſare, non poteris, vel è iugularibus, vel cruralibus venis & arteriis apertis vllo conatu maſſæ ſanguineæ, vltra partem mediam elicere. Nec lanio, ſi boui (poſtquam eius caput percuſſerit, & attonitum reddiderit) iugulum prius non ſecuerit, quam cor pulſare deſierit, totum ſanguinem exhaurire inde poterit.

Denique hinc de Anaſtomoſi venarum & arteriarum, vbi ſit & quomodo ſit, & qua de cauſa, nemo hactenus, ſuperea, recte quidquam dixiſſe licet ſuſpicari. ego in illa diſquiſitione iam ſum.

CAPVT X.

Primum ſuppoſitum de copia pertranſeuntis ſanguinis è venis in arterias, & eſſe ſanguinis circuitum ab obiectionibus vindicatur, & experimentis vlterius confirmatur.

HActenus primum ſuppoſitum confirmatum eſt, ſiue res ad calculum reuocetur, ſiue ad experimenta, & autopſiam referatur. videlicet:

licet: quod ſanguis per tranſeat in arterias, maiori copia continue, quam ab alimento ſuppeditari poſſit, ita vt tota maſſa breui ſpatio illac permanſeunte, neceſſe ſit, vt circuitus fiat, & ſanguis regrediatur.

Verum ſi quis hic dicat, quod magna copia poſſit per tranſire & non neceſſe circuitum fieri, quin ab aſſumptis reſarcire contingat, & exemplo eſſe lactis in mammis prouentus: vacca enim vna die lactis congios tres, vel quatuor vel ſeptem, vel amplius reddit, mulier itidem duas, vel tres heminas alendo infantem, vnum vel duos, ſingulis diebus præbet, quas ab aſſumptis reſtitui manifeſtum eſt. Reſpondendum, quod cor tantundem, vel amplius, vna hora, vel altera, computatione facta, remittere conſter.

Sin vero nondum perſuaſus, inſtaret, vſque dicendo, quod licet diſſecta arteria, quaſi data & aperta via, præter naturam contingat ſanguinem cum impetu effundi; non tamen ita contingere integro corpore & non dato exitu, & arteriis plenis, vel ſecundum naturam conſtitutis, tantam copiam per tranſire, tam breui ſpatio, adeo, vt regreſſum fieri ſit neceſſe. Reſpondendum, quod ex ante dicta computatione, ſubducta ratione, apparet, quantum cor repletum vlterius continet in ſua dilatatione quam in conſtrictione, tantundem (maiori ex parte) ſingulis pulſationibus emitti, & proinde in tanta copia, per tranſire integro corpore, & ſecundum naturam conſtituto.

Sed in ſerpentibus & piſcibus quibuſdam, ligando venas per aliquod ſpatium infra cor, videbis ſpatium inter ligaturam & cor valde cito inaniri, ita vt regredi ſanguinem (niſi aut opſiam neges) aſſerere neceſſe habeas. Poſterius etiã idẽ clare patebit in ſecundi ſuppoſiti cõfirmatione.

Hæc omnia vno exemplo confirmantes, concludamus, quo fidem oculis propriis adhibere vnuſquiſque poſſit, ſi anguem viuum diſſecuerit, videbit plus quam per integram horam cor placide, diſtincte, pulſare & ſeſe tanquam vermem in conſtrictione (cum oblongum ſit) ſecũdum longitudinem contrahere, propellere; in Syſtole albidiori colore eſſe contra in Diaſtole; & rèliqua pene omnia, quibus euidenter hanc veritatem cõfirmatum iri diximus (hic enim omnia longiora & diſtinctiora magis ſunt) ſed hoc peculiariter & luce clarius meridiana experiri licet. Vena caua partem inferioré cordis ſubingreditur, exit arteria parte ſuperiori, iã cõprehenſa, vena caua vel teuacuſis, vel digito & pollice, ſanguiniſq; curſu intercepto, per aliquod ſpatiũ infra cor videbis

expulſu

expulſu, ſtatim pene inaniri illam partem intra digitos & cor, ſanguine exhauſto à cordis pulſu, ſimul cor albidiori multo colore eſſe, etiam in dilatatione ſua, & ob defectum ſanguinis minus eſſe & languidius tandem pulſare, ſic vt emori denique videatur. Contra ſtatim ſoluta vena, color & magnitudo redeunt cordi; poſtea ſi relinquas venam, & arterias ſimiliter per aliquam diſtantiam à corde ligaueris, vel compreſſeris, videbis contra illas turgere, in parte comprehenſa vehementer, & cor vltra modum diſtendi purpureum colorem contrahere vſque ad liuorem & tandem opprimi ſanguine, ſic vt ſuffocatum iri credas: ſoluto vero vinculo rurſus ad naturalem conſtitutionem in colore magnitudine pulſu redire.

Ecce iam, duo ſunt genera mortis, extinctio ob defectum & ſuffocatio ob copiam, hic ad oculos vtriuſque exemplum habere licet, & dictam veritatem autopſia in corde confirmare.

CAPVT XI.

Secundum ſuppoſitum confirmatur.

SEcundum confirmandum à nobis, quo clarius intuentibus appareat, annotanda ſunt experimenta quædam, ex quibus patet ſanguinem in quodcunque membrum per arterias ingredi, & per venas remeare, & arterias vaſa eſſe differentia ſanguinem à corde, & venas vaſa, & vias eſſe regrediendi ſanguinis ad cor ipſum. Et quod in membris, & extremitatibus ſanguis vel per Anaſtomoſin immediate, vel mediate per carnis poroſitates, vel vtroque modo tranſire ab arteriis in venas, ſicut ante in corde & thorace è venis in arterias: vnde in circuitu moueri illinc huc, & hinc, illuc, è centro in extrema ſcilicet, & ab extremis rurſus ad centrum manifeſtum fiat.

Poſtea quin etiam computatione facta ſimiliter, manifeſtum ibidem erit, de copia, quæ neque ab aſſumptis poſſit ſuppeditari, neque ad nutritionem neceſſario requiratur.

Simul etiam de ligaturis manifeſtum erit, & quare ligaturæ attrahant, & quod neque calore, neque dolore, neque vi vacui, neque vlla ante hac cognita cauſa & ſimiliter ligaturæ quam commoditatem & vſum afferre poſſint in medicina, & quomodo hæmorrhagiam ſupprimunt, & prouocant, & qua de cauſa gangrenæ & mortificationes membrorum

brorum inducunt, & ſic in caſtratione animalium quorundam, & tumorum carnoſorum & verrucarum exemptione vſui ſunt.

Enim vero, quod nemo harum omnium cauſas & rationes recte aſſecutus ſit, hinc factum eſt, vt omnes fere, ex antiquorum ſententia, in morbis curandis, proponant, & conſulant, ligaturas, pauci vero, recta earum adminiſtratione, curationibus ſuis aliquid adiumenti afferant.

Ligatura alia ſtricta eſt, alia mediocris.

Strictam ligaturam dico, cum ita arcte vndique conſtrictum membrum ſit faſcia, vel laqueo, vt vltra ipſam ligaturam nullibi arterias pulſare percipiatur, tali vtimur in membrorum excisione fluxui ſanguinis proſpicientes; & tali etiam vtuntur in caſtratione animalium, & tumorum ablatione, qua ligatura affluxu alimenti, & caloris omnino intercepto, tabeſcere, & emori teſticulos, atque ingentes ſarcoſes, & poſt ea decidere, videmus.

Mediocrem vero dico ligaturam, quæ vndique membrum comprimit, ſed citra dolorem, & ſic, vt vltra ligaturam aliquantulum arteriæ pulſare ſinat, qualis, attractione, & in ſanguinis miſſione vſui eſt, nam licet ſupra cubitum fiat ligatura, tamen arterias in carpo aliquantulum pulſare tactu percipias, ſi recte in phlebotomia fiat ligatura.

Iam experimentum fiat in brachio hominis, vel adhibita faſcia quali in ſanguinis miſſione vtuntur; vel ipſius manus fortiore comprehenſione, quod quidem commodius fit in macilento corpore, & cui venæ ſint ampliores, & quando (calefacto corpore) calent extrema, & maior quantitas ſanguinis in extremitatibus fuerit, & pulſus vehementiores: omnia enim ibi euidentiora apparebunt.

Facta itaque ſtricta ligatura quam arcte fieri poteſt vt quis eum ferat conſtringendo, obſeruare licet primum. Quod vltra ligaturam videlicet verſus manum, non pulſabit in carpo vel vſpiam arteria. Deinde, immediate ſupra ligaturam incipit arteria, altius ſuam Diaſtolem habere, & magis, & altius, & vehementius pulſare, & prope ipſam ligaturam, æſtu q. quodam intumeſcit, ac ſi fluxũ interceptum, & tranſitum inhibitum perrumpere, & referare conaretur: magiſque arteria, quam par ſit ibi repleta apparet Denique manus ſuum colorem retinebit, & conſtitutionem, ſolum tractu temporis refrigerari aliquantulum incipiet, nihil vero attrahitur in eam.

Poſtquam per aliquod ſpatium permanſit iſta ligatura, derepente paululum ſoluatur in mediocrem, quali vt dixi in ſanguinis miſſione vtuntur: & obſeruandum.

Manum totam ſtatim colorari, & diſtendi, & eius venas tumidas, & varicoſas fieri; & ſpatio decem vel duodecim pulſationum illius arteriæ, multo ſanguine impulſo, atq; impacto refertiſſimam manum cernes, & ab illa ligatura mediocri, multam copiam ſanguinis aff tum attractam eſſe, abſque dolore, vel calore vel fuga vacui, vel vlla alia antehac commemorata cauſa.

Si quis diligenter in ipſo illius ſolutionis momento prope ligaturam digitum ad arteriam iam pulſantem applicauerit, quaſi ſubtus præterlabentem ſanguinem ſentiet.

Ipſe porro cuius in brachio fit experimentum, ab ipſa ſolutione ligaturæ ſtrictæ in mediocrem, plane calorem, & ſanguinem, pulſu ingredientem, quaſi ſemoto obſtaculo, illico ſentiet, & aliquid ſecundum ductum arteriarum, tanquam confeſtim inflatum, & ſparſim per manum tranſmiſſum, percipiet, & continuo calefieri manum & diſtendi.

Quemadmodum in ſtricta ligatura, arteriæ ſupra ligaturam diſtendantur, & pulſent, non infra: ita hac mediocri contra, venæ infra ligaturam turgent, & renitentes fiunt, ſupra vero nequaquam & arteriæ minores. Imo, ſi venas tumidas compreſſeris, (niſi valde fortiter) vix ſupra ligaturam, aut ſanguinem diffundi aut venas diſtendi conſpicies.

Ita ex his cuiuis diligentius obſeruanti, facile eſt noſcere, ſanguinẽ ingredi per arterias, ipſarum enim ſtricta ligatura nihil attrahitur, manus colorem ſeruat, nihil influit, neque fit diſtenſio. ipſis vero paululum ſolutis (vt in mediocri ligatura) vi & impulſu affatim ſanguinem intus trudi, manum tumidam fieri manifeſtum eſt, vbi ipſæ pulſant, ſcilicet, ſanguis profluit, vt mediocri ligatura in manu: vbi vero non, vt in ſtricta, nequaquam, niſi ſupra, ligaturam. Cum interim venis compreſſis, nihil per ipſas influere poteſt: cuius hoc eſt ſignum, quod infra ligaturam tumidiores multo ſunt, quam ſupra, & quam dempta ligatura ſolent eſſe, & quod compreſſæ, nihil ſuperioribus ſuggerunt ita, quod ligatura impediat regreſſum ſanguinis per venas, ad ſuperiora eaſque infra ligaturam tumidas faciat permanere, clare patet.

Arteriæ vero iuſta de cauſa, non obſtante mediocri ligatura, vi & impulſu cordis ab internis corporis partibus foras vltra ligaturam ſanguinem trudunt, & iſta eſt differentia ſtrictæ ligaturæ à mediocri quod illa (ſtricta ligatura) non ſolum tranſitum ſanguinis in venis, ſed in arteriis

teriis intercipiat: hæc (quæ mediocris) vim pulsificam, quo minus vltra ligaturam se exporrigat, ad extimasque corporis partes propellat, sanguinem non impediat.

Adeo vt sic ratiocinari liceat: mediocri ligatura cũ venas turgidas distẽtas esse, & manũ plurimo sanguine impleri vidimus, vnde fit hoc? aut n pervenas, aut per arterias, aut per cœcas porositates, infra ligaturam sanguinis aduenit: è venis, non potest: per cœcos ductus, minus: ergo per arterias secundum quod dictum, necesse est: per venas influere non posse, patet; cum non exprimi retro sanguinem contingat supra ligaturam, nisi ablata omni ligatura, quando subito omnes venas detumescere, & sese in superiores partes exonerare, manum dealbari, & sursum omne prius collectum & tumorem & sanguinem affatim euanescere videtur.

Amplius sentiet ipse, cui ita, post multum spatium ligatum corpus aut brachium erat, & manus tumidæ pauloque frigidiores inde redditæ, sentiet (inquam) de solutione mediocris ligaturæ, frigidum quid sursum vsque ad cubitum vel axillas obrepere, vna scilicet cum reuertente sanguine, quem ego frigidi sanguinis recursum (post sanguinis missionem) ad cor vsque (soluto vinculo) in causa fuisse lipothymiæ arbitrarer, quæ etiam robustis aliquando superuenire vidimus, & maxime à solutione ligaturæ, quod vulgo dicunt à conuersione sanguinis.

Præterea, cum statim, à solutione strictæ ligaturæ in mediocrem immissionem sanguinis per arterias, continuo venas intumescere videmus infra ligaturam comprehensas, non autem arterias; Signum est & sanguinem ab arteriis in venas & non contra permeare, & aut anastomosin vasorum esse, aut porositates carnis, & partium solidarum peruias sanguini esse. Item signum est venas plurimas inter se se communicare, quod in ligatura mediocri (supra cubitum facta) multæ attolluntur simul & turgent: ex vna autem venula scalpello, exitu sanguini dato, omnes statim detumescunt & in illam vnam sese exonerantes subsidunt simul pene omnes.

Hinc vnusquisque potest causas attractionis, quæ fit per ligaturas, & forsan omnis fluxionis cognoscere, videlicet (quẽadmodum in manu, per istam ligaturam, quam dico mediocrem) compressæ sunt venæ & sanguis exire non potest. Ita cum per arterias vi (scilicet cordis) impingitur, non potens exire inde vt repleatur, distendatur pars necesse est.

Alias enim qui fieri poteſt? Calor & dolor, & vis vacui attrahunt quidem, ſed vt impleatur tantum pars, non vt diſtendatur aut tumefiat vltra naturalem conſtitutionem, & ob infractum, & arcte impactum vi ſanguinem tam violenter, tam ſubito opprimatur, vt caro continui ſolutionem pati, & vaſa diſrumpi cernantur, nuſquam hoc aut calore, aut dolore, aut vi vacui fieri poſſe, credibile, aut demonſtrabile eſt.

Inſuper & ligatura, contingit, attractionem fieri, abſque omni dolore, colore aut illa vi vacui. Quod ſi à dolore aliquo accideret ſanguinem attrahi, quo modo ad cubitum, ligato brachio, infra ligaturã intumeſcunt, & manus, & digiti & venæ varicoſæ? cum propter ligaturæ compreſſionem eo peruenire ſanguis per venas non poteſt; atque quare ſupra ligaturam, neque tumoris, aut repletionis ſignum, neque venarum turgeſcentiæ, neque omnino attractionis, aut affluxus veſtigium appareat.

Sed attractionis infra ligaturam, & tumefactionis vltra naturæ modum, in manu, & digitis, hæc cauſa manifeſta; nempe, quod ſanguis cũ impetu, & affatim ingrediatur, exire vero nequeat. An illa vero omnis tumoris cauſa (vt eſt apud Auicen.) & omnis redundantiæ opprimentis in parte? quia viæ ingreſſus apertæ, egreſſus clauſæ, vnde abundare, & in tumorem attolli neceſſe eſt.

An hinc etiam contingat in tuberculis inflammatoriis, quod quouſque tumor incrementum capeſcit, & non ſit in vltimo ſtatu, ſentitur eo loci pulſus plenus, præſertim calidioribus tumoribus in quibus incrementum de repente fieri ſolet, ſed hæc poſterioris diſquiſitionis ſunt, vti an etiam hinc contingat, quod in me ipſo caſu expertus ſum. Ego è curru delapſus aliquando fronte percuſſus, quo loco arteriæ ramulus à temporibus prorepit, ſtatim ab ipſa percuſſione, ſpatio fere viginti pulſationum tumorem oui magnitudine, abſque vel calore vel multo dolore, paſſus ſum, propter videlicet arteriæ vicinitatem, in locum contuſum: ſanguis affatim, magis & velocius impingebatur.

Hinc vero apparet, qua de cauſa in phlebotomia, quando longius proſilire & maiori impetu exire volumus, ſupra ſectionem ligamus, nõ infra; quod ſi per venas inde efflueret tanta copia à partibus ſuperioribus, ligatura illa non modo non adiuuaret ſed impediret, & enim inferius ligandum verisimilius erat, quo ſanguis inhibitus vberius exeat, ſi ex partibus ſuperioribus eo per venas deſcendens per venas emanaret: ſed cum aliunde per arterias impellitur in venas inferiores, in quibus regreſſus

regreſſus per ligaturam præpeditur, venæ turgent, & diſtentæ ipſum maiori impetu per orificium elidere & longius eiicere poſſunt, ſoluta vero ligatura, viaque regreſſus aperta ecce non amplius, niſi guttatim decidit, & quod omnes norunt, ſi vel vinculum ſolueris in adminiſtranda phlebotomia vel infra ligaueris vel ſtricta nimis ligatura, mébrum conſtrinxeris, tum ſanguis ab (que impetu exit; Quia ſcilicet via ingreſſus & influxus ſanguinis per arterias intercep'a ſit. Stricta illa ligatura atteriarũ, aut regreſſus liberior datur per venas, ligatura ſoluta.

CAPVT XII.

Eſſe ſanguinis circuitum ex ſecundo ſuppoſito confirmato.

HÆc cum ita ſint; conſtat confirmatum iri etiam aliud, quod antea per cor continuo ſanguinem tranſire dicebam: videmus enim ab arteriis ſanguinem in venas dimanare, non è venis in arterias: videmus inſuper vel pene totam maſſam ſanguinis exhauriri poſſe ab ipſo brachio (idque vna vena cuticulari ſcalpello aperta, ſi fiat ligatura decẽs) videmus præterea, ita impetuoſe & affatim effundi, vt non ſolum breui & cito euacuati qui ante ſectionem in brachio intra ligaturam comprehenſus erat ſanguis, ſed ex toto brachio & toto corpore tam arteriis quam venis.

Quare confiteri neceſſe eſt, primo vi & impetu ſuppeditari, & quod vi impingatur intra ligaturam; vi enim & impulſu exit: & proinde à cordis pulſu & robore, vis enim & impulſio; ſanguinis ſolum à corde.

Deinde à corde prouenire hunc fluxum, & per cor tranſitu facto è venis magnis hac effluere, ſimiliter confiteri neceſſe, cum intra ligaturam per arterias ingreditur non per venas, & arteriæ nuſquam ſanguinem è venis recipiunt niſi è ſiniſtro ventriculo cordis.

Neque omnino aliter ex vna vena (facta ſupra ligatura) tantam copiam exhaurire vllo modo potuiſſet, præſertim tam impetuoſe, affatim, tam facile, tam ſubito, niſi à corde, vi, & impulſu conſecutio fiat hoc dicto modo.

Et ſi hæc ita ſint: hinc præterea de copia computationem facere, & de circulari motu ſanguinis argumentari apertiſſime poſſumus. Si etenim in phlebotomia (eo quo ſolet prorumpere effuſione & impetu) ſi

quis per semihoram prouenire sineret, nulli dubium, quin maxima (ipsius sanguinis) parte exhausta, lypothymia & syncope aduentarent, & non solum arteriæ, sed & venæ magnæ pene inanitæ forent. Transire ergo rationabile est, semihoræ illo spatio tantundem è vena magna per cor in aortam. Vlterius si quot vnciæ per vnum brachium perfluant: vel quot in 20. vel 30. pulsationibus intra mediocrem ligaturam trudantur sanguinis, supputares; daret profecto existimandi copiam, quantum per aliud brachium interea per vtrumque crus, per collum vtrinque, & per alias omnes arterias; & venas corporis interim pertranseat; quibus omnibus fluxus per pulmones, & cordis ventriculos, nouum continuo sanguinem suggerere debet, idque è venis necessarium est, circuitum fieri; cum nec suppeditari ab assumptis possit, & longe plus est, quam partium nutritioni congruens erat.

Amplius obseruandum, quod in administranda phlebotomia, quãdoque contingit hanc veritatem confirmasse. Nam recte brachiũ quanquam ligaueris, & scalpello debito modo dissecueris, aptari orificius, & omnibus rite administratis, tamen si timor, aut ex quauis alia causa, aut animi pathemate, lipopsychia adueniat, & cor languidius pulsat, nullo modo sanguis exibit, nisi guttatim: præsertim si ligatura strictior paulo facta sit. ratio est, quia compressam arteriam languidior pulsus & impellens vis infirmior recludere, & sanguinem intra ligaturam trudere non valet: imo per pulmones deducere, aut è venis in arterias copiosa transferre, eneruatum & languidum cor non potest. Sic eodem modo, & eisdem de causis contingit, & mulierum menstrua, & omnem hæmorrhagiam sedari. Ex contra: iis etiam hoc patet; quoniam redintegrato animo, amoto metu, cum ad se redeunt, iam adaucto robore pulsificante; arterias statim vehementius pulsare etiam in parte ligata, in carpo moueri, & sanguinem per orificium longius prosilire, continuo ductu videbis.

CAPVT XIII.

Tertium suppositum confirmatur, & esse sanguinis circuitum ex tertio supposito.

HActenus de copia pertranseuntis sanguinis per cor, & pulmones, in centro corporis, & similiter ab arte. iis in venas in habitu corporis. Restat, vt, quomodo per venas ab extremitatibus, ad cor, retro sanguis

guis permeat, & quomodo venæ ſint vaſa deferentia ſolum ſanguinẽ, ab extremitatibus ad centrum, explicemus: quo facto, tria illa propoſita fundamenta, pro circuitu ſanguinis fore aperta, vera, ſtabilia, ad fidem ſufficienter faciendam exiſtimamus.

Hoc autem ex valuulis, quæ in ipſis venarum cauitatibus reperiuntur, & ex illarum vſu, & ocularibus experimentis, ſatis erit apertum.

Clariſſimus Hieronym. Fabr. ab Aq. pendent: peritiſſimus Anatomicus & venerabilis ſenex, vel vt voluit Doctiſs. Riolanus Iac. Siluius. primus in venis membraneas valuulas delineauit figura ſigmoides, vel ſemilunares portiunculas tunicæ interioris vena ume eminentes tenuiſſimas. Sitæ ſunt diſtantibus in locis vario modo in vatiis homi ibus ad venæ latera connatæ, ſurſum, verſus venarum radices ſpectantes, & in mediam capacitatem venæ, ambæ (vt plurimum enim duæ ſunt) inuicem reſpicientes, atque ſe inuicem contingentes, & in extremitatibus ita cohærere, copulari aptæ: vt ſi quid è radice venarum in ramos vel è maioribus in minores permearet, omnino impediant, & ita ſitæ: vt ſequentium cornua præcedentium conuexæ medium (& ſic alternatis vicibus) reſpiciant.

Harum valuularum vſum rectum inuentor non eſt aſſecutus, nec alii addiderunt: non eſt enim ne pondere deorſum ſanguis in inferiora totus ruat: Sunt namq; ie in iugularibus deorſum ſpectantes, & ſanguinem ſurſum prohibentes fieri, & non vbique ſurſum ſpectantes, ſed ſemper verſus radices venarum & vbique verſus cordis locum: Ego, vt alii etiam, aliquando in emulgentibus reperi, & in Ramis miſenterii verſus venam cauam & portam ſpectantes: adde inſuper quod in arteriis nullæ ſunt, & notare licet, quod canes, & boues omnes habent valuulas in diuiſione crutalium venarum, ad principium oſſis ſacri, vel in ramis illis prope ooxendicem, in quibus nil tale timendum propter erectam ſtaturam.

Nec ob metum Apoplexiæ (vt alii dicunt) ſunt in iugularibus valuulæ, quia materia in ſomno potius per arterias ſoporales influere in caput apta eſſet.

Nec vt ſanguis in diuaricationibus ſubſiſtat, in ramos exiles, & non totus in magis apertos, & capaces irrueret: poſitæ enim ſunt vbi nullæ diuaricationes, licet frequentiores conſpici fateor, vbi diuaricationes ſunt.

Nec vt motus ſanguinis à centro corporis retardetur ſolum (tarde

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enim satis sua sponte, è maioribus in minores ramulas intrudi, è massa & fonte separari, aut è locis calidioribus in frigidiora migrare; verisimilius est) Sed omnino valuulæ factæ sunt, ne à venis magnis in minores moueretur sanguis & sic illas dilaceratet, aut variocosas efficeret, neue à centro corporis in extrema: sed potius ab extremitatibus ad cẽtrum progrederetur, ita huic motui valuulæ tenues facile recludun-tur, cõtra ium omnino supprimunt, & sic positæ & ordinatæ vt si quid per cornua superiorum minus prohiberetur transitu, sed quasi per ri-mas elaberetur conuexitas subsequentium transuersim posita excipe-ret, & sisteret ne vlterius transiret.

Ego illud sæpissime in dissectione venarum expertus sum, si à radice venarum initio facto, versus exiles venarum ramos Spi: illum mitterem (quanto potuerim artificio) ob impedimentum valuularum longius impellere, non potuisse: contra vero forinsecus è ramulis radicem ver-sus facillime, & pluribus in locis valuulæ binæ ad inuicem ita positæ, & aptatæ, vt ad amussim (dum eleuantur) in media venæ cauitate co-hæreant & vnian tur, extremitatibus conuexis inuicem; vt neque visu, cernere, neque satis explorare rimulam aut coitum liceret, contra vero forinsecus intro immisso stylo cedunt, & (valuularum, quibus cursus fluminum inhibentur in morem) facillime reclinantur, vt motum san-guinis profectum à corde, & vena caua intercipiant, & ad amussim plu. ribus in locis eleuati inuicem dum clauduntur, omnino inhibeant & supprimant, & siue sursum ad caput, siue deorsum ad pedes, siue ad late-ra brachii sanguinem à corde moueri (ita sunt constitutæ) vt nusquam sinant, sed motui omni sanguinis qui à maioribus venis auspicatus, in minores desinat, aduersentur & obsistant: ei vero qui à venis exili-bus incipiens in maiores desinat, obsecundent liberamque & pa-tentem viam exped.ant.

Sed quo veritas hæc apertius eluceſcat; ligetur brachium supra cu-bitum viuo homine, tanquam ad mittendum sanguinem A A per in-terualla apparebunt, præcipue in rusticis & varicosis, tanquam modi quidam & tubercula B.C.D D.E.F. non solum vbi est diuaricatio E.F. sed etiam vbi nulla [C.D.] & isti nodi à valuulis fiunt. Hoc modo ap-parentibus in exteriori parte manus vel cubiti si à nodo inferius polli-ce vel digito comprimendo sanguinem, & de nodo illo siue valuula detraxeris] H. 2. figur.] videbis nullum (inhibente omnino valuula) subsequi posse & venæ portionem (H. O. secũdæ fig.) infra tuberculũ & digi-

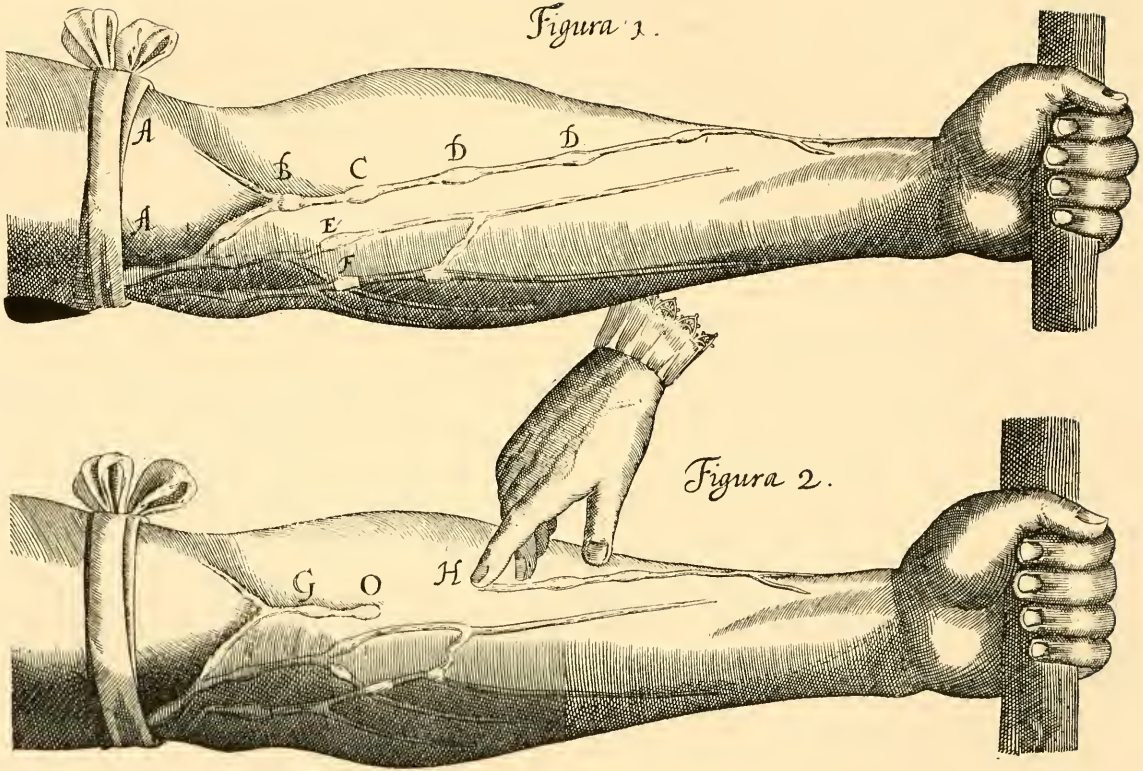
Figura 1.
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Figura 2.
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catione, tantum ſanguinis hoc modo per vnius venæ partem, in non lõgo tempore tranſmiſſum reperies, vt de circuitu ſanguinis, ab eius celeri motu, te perſuaſiſſimum puto ſentires.

Sed ne hoc experimento naturæ vim afferre dicas, in longe diſtantibus valuulis, illud ſi feceris, obſeruando, ablato pollice, quam cito quã celeriter ſanguis ſurſum percurrat, & venam ab inferiori parte repleat, illud ipſum exploratum tibi fore non dubito.

CAPVT XIV.

Concluſio demonſtrationis de ſanguinis circuitu.

IAm denique noſtram de circuitu ſanguinis ſententiam ferre, & omnibus proponere liceat.

Cum hæc confirmata ſint omnia, & rationibus & ocularibus experimentis, quod ſanguis per pulmones & cor, pulſu ventriculorum pertranſeat, & in vniuerſum corpus impellatur, & immittatur, & ibi in venas & poroſitates carnis obrepat, & per ipſas venas vndique de circũferentia ad centrum ab exiguis venis in maiores remeet, & illinc in venam cauam, ad auriculam cordis tandem veniat, & tanta copia, tanto fluxu, refluxu, hinc per arterias illuc, & illinc per venas huc retro, vt ab aſſumptis ſuppeditari non poſſit, atque multo quidem maiori (quã ſufficiens erat nutritioni) prouentu. Neceſſarium eſt concludere circulari quodam motu in circuitu agitari in animalibus ſanguinem; & eſſe in perpetuo motu, & hanc eſſe actionem ſiue functionem cordis, quam pulſu peragit, & omnino motus & pulſus cordis cauſam vnam eſſe.

CAPVT XV.

Sanguinis circuitus rationibus veriſimilibus confirmatur.

SEd hoc etiam ſubiungere non abs re fuerit, quod ſecundum communes quaſdam ratiocinationes, ita eſſe & conueniens ſit, & neceſſarium. Primum (Ariſtot. de reſpirat. & lib. 2. & 3. de partibus animalium & alibi) cum mors ſit corruptio propter calidi defectum & viuẽtia omnia,

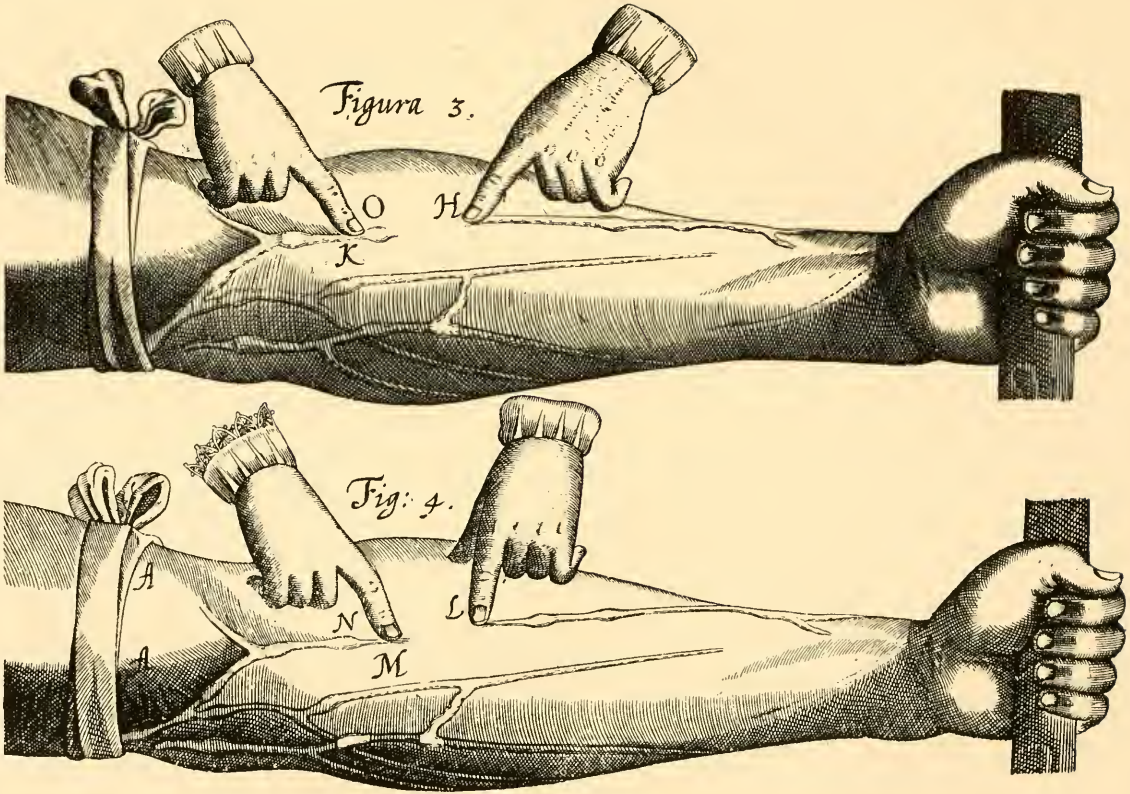
Figura 3.
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Fig: 4.
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tia omnia calida, morientia frigida, locum, & originem esse oportet caloris, quasi lares focumque, quo naturæ fomites, & primordia ignis natiui contineantur, & conseruentur, à quo calor & vita in omnes partes tanquam ab origine profluant, & alimentum adueniat, & concoctio, & nutritio, & omnis vegetatio dependeat.

Hunc autem locum cor esse, & hoc principium vitæ, & hoc quo dictum est modo, neminem vellem dubitare.

Sanguini itaq; motu opus est, atque tali, vt ad cor rursus reuertatur, nam in externas corporis partes emandatus longe (vt Arist. 2. de part. animal.) à suo fonte, immotus coagularetur. (motu enim in omnibus calorem & spiritus generari, & conseruari videmus, quiete euanescere) tum à frigore extremorum & ambientis consistens aut gelatus sanguis & spiritibus (vti in mortuis) destitutus: vt rursus à fōte, & origine, tam calorem quam spiritus, & omnino præseruationem suam repetat, & reuertendo redintegraret; necesse fuit.

Videmus vti à frigore exteriori extremitates aliquando algeant vt liuidi & nasus, & manus & genæ quasi mortuorum appareant & sanguis in ipsis (qualis cadauerum, locis pronis solet decumbere) liuorē cōsistat, & membra adeo torpida, & ægre mobilia euadant, vt vitam pene amisisse videantur. Nullo modo profecto rursus (præsertim tam cito) calorem, colorem, & vitam recuperarent, nisi nouo, ab origine affluxu, & appulsu caloris fouerentur: Attrahere enim quomodo possunt, quibus calor & vita pene extincti sunt? aut quibus meatus condensati, & gelato sanguine repleti, quomodo adueniens admitterent alimentum, & sanguinem; nisi contentum dimitterent? & nisi omnino cor esset, & huiusmodi principium; vbi, his refrigeratis remanerent vita & calor (vt Aristot. respirat. 2.) & vnde nouo, per arterias transmisso, sanguine, calido, spiritibus imbuto. Et quod frigefactum & effætum est propellatur & omnes particulæ calorem languidum & vitalem fomitem, pene extinctum repararent.

Hinc ita est, vt cęteris omnibus partibus & vitam restitui, & sanitatē recuperari, corde illęso cōtingere possit: Corde vero vel refrigerato, vel vitio graui aliquo affecto, totū animal pati, & corruptū iri necesse sit, cū principiū corrūpitur & patitur. Nihil n. est (vt Arist. 3. de partib. animal) quod aut ipso, aut cæteris quæ ab ipso pēdeant, pbere auxiliū potest. Et hinc obiter forsan ratio est, cur mœrore, amore, inuidia, curis & huiusmodi, tabes & extenuatio contingant aut cacochymia & prouentus

cruditatum, quæ & morbos omnes inducant & homines conficiant: omne namque animi pathema, quod cum dolore, & gaudio, ſpe, aut anxietate humanas exagitat mentes, & ad cor vſque pertingit, & ibi mutationem à naturali conſtitutione intemperie & pulſu & reliquis facit; illud in principio totum alimentum inquinando, & vires infirmando, minime mirum videri debet, quod varia genera morborum incurabilium in membris & corpore ſubinde procreat, quandoquidem totum corpus, in illo caſu vitiato alimento & inopia calidi natiui laborat.

Præter hæc cum alimento viuant omnia animalia interius cõcocto, neceſſe eſt concoctionem perfectam eſſe, & diſtributionem, & proinde locum & conceptaculum adeſſe, vbi perficiatur alimentum & vnde deriuetur in ſingula membra; hic locus autem cor eſt; cum ſolum ex omnibus partibus (non ſolum in vena & arteria coronali priuato vſui) ſed in cauitatibus ſuis tanquam in ciſternis, & promptuario (auriculis ſcilicet & ventriculis) publico vſui, ſanguinem continet: reliquæ omnes partes ſui ipſius tantum cauſa & priuato vſui, in vaſibus duntaxat habent) & cum cor ſolum ita ſitum & conſtitutum, vt inde pulſu ſuo, in omnes partes (idque ſecundum iuſtitiam & proportionem cauitatum arteriarum, vnicuique particulæ inſeruientium) æqualiter diſpenſat, diſtribuit, & indigentib. (quaſi è theſauro & fonte) hoc modo largitur.

Amplius ad hanc diſtributionem & motum ſanguinis, impetu & violentia opus eſt, & impulſore, quale cor eſt: Tunc quia ſanguis ſponte ſua (quaſi verſus principium, vel pars ad totum, vel gutta aquæ ſparſæ ſuper tabulam ad maſſam) facile concentratur & coit: (vti à leuibus cauſis ſolet celerime frigore, timore, horrore & huiuſmodi cauſis aliis.) Tum vltra quia è venis capillaribus in paruas ramificationes & inde in maiores exprimitur motu membrorum & muſculorum compreſſione, procliuis eſt magis & pronus ſanguis, vt è circumferentia moueatur in centrum, quam è contrario (quamquam valuulæ impedimento nullæ forent) vnde vt principium relinquat, & loca ſtricta & frigidiora iniret, & contra ſpontaneum moueretur. tum violentia opus habet ſanguis tum impulſore, quale cor ſolum eſt, & eo quo dictum eſt modo.

CAPVT XVI.

Sanguinis circuitus ex conſequentibus probatur.

SVnt inſuper problemata, ex hac veritate ſuppoſita, tanquam conſequentia, quæ ad fidem faciendam, veluti à poſteriore non ſunt inutilia,

tllia, & quæ cum aliis multa ambiguitate & obſcuritate inuoluta videantur eſſe: hinc & rationem & cauſas aſſignari facile patiantur.

Quemadmodum quæ in contagione videmus, in ictu venenato, & ſerpentum morſu, aut canis rabidi, in lue venerea, & huiuſmodi quomodo illæſa particula contacta tamen totum habitum contingit vitiari (vti lues venerea illæſis aliquando genitalibus primo omnium vel Scapularum, vel capitis dolore, vel aliis Symptomatibus ſeſe prodere ſolet) & vulnere facto à morſu canis rabidi, curato, febrem tamen, aut reliqua horrenda Symptomata ſuperueniſſe experti ſumus. Quoniam primum, in particulam impreſſum contagium, vna cum reuertente ſanguine ad cor fertur; & inde totum corpus poſtea inquinare poſſe hinc patet: In tertiana febr', morbifica cauſa principio cor perens, circa cor & pulmones immoratur, & anheloſos, ſuſpirioſos, ignauos facit, quia principium aggrauatur vitale & ſanguis in pulmones impingitur, incraſſatur, non tranſit (hocego ex diſſectione illorum qui in principio acceſſionis mortui ſunt, expertus loquor) quando ſemper pulſus frequentes parui, & quandoque inordinati ſunt; adcucto vero calore, attenuatione facta materiæ, apertis viis, & tranſitu facto incaleſcere vniuerſum corpus, pulſus maiores fieri vehementiores, & fit paroxyſmus febrilis: dum calor, ſcilicet, præternaturalis accenſus in corde, inde in totum corpus per arterias diffunditur, vna cum materia morbifica; quæ co modo à natura exuperatur, & diſſoluitur.

Cur etiam exterius applicata medicamenta vires intro exercent ſuas, ac ſi intro ſumpta eſſent, hinc conſtet (Colocynthis & Aloe ventrem ſoluunt, Cantharides vrinas mouent, Allium plantis pedum alligatum expectorat, & cordi alia roborat, & huius generis infinita) venas per orificia ab exterius admotis, abſorbere aliquid & intro cũ ſanguine deferre (non alio modo, quam illæ in meſenterio, ex inteſtinis Chelum exugunt & ad iecur vna cum ſanguine apportant) non irrationabile eſt forſan dicere.

In meſenterio etenim ſanguis, per arterias Celiacas meſentericam ſuperiorem & inferiorem, ingreſſus; ad inteſtina progreditur: à quibus vna cum Chylo in venas attracto per illarum venarum frequentiſſimas ramificationes in portum iecoris reuertitur, & per ipſum in venam cauam ſic contingit, vt ſanguis in his venis eodem ſit imbutus & colore & conſiſtenti, qua in reliquis, contra quam plures opinantur: nec duos contrarios motus in omni Capillari propagine Chyli ſurſum, ſanguinis

deorsum incõuenienter fieri improbabiliter existimare necesse est. Sed an non summa naturæ prouidentia hoc fit; si enim Chylus cum sanguine, crudus cum concocto, æquis portionibus confunderetur, non concoctio transmutatio & sanguificatio exinde proueniret, sed magis (cũ inuicem actiua & passiua sint) ex alteratorum vnione mistio, & mediũ quid, vt in perfusione vini cum aqua & oxicrato; iam vero quando multo cum præterlabente sanguine exigua portio Chyli hoc modo admista sit, & quasi nulla notabili proportione, cõtingit illud facilius (quod ait Aristoteles) cum vna gutta aquæ addita vini dolio, aut è contra, totum non mistum, sed vel vinum vel aqua. Ita in venis meseraicis dissectis, non Chymus non Chylus & sanguis, aut separati, aut confusi reperiuntur, sed idem qui in reliquis venis sanguis & colore, & consistentia ad sensum apparet. In quo tamen quia Chyli quidda inconcoctũ (licet insensibiliter) inest. Natura iecur appositi, in cuius mæandris moras trahat & pleniorem transmutationem acquirat, ne præmature crudum ad cor perueniens, vitæ principium obrueret. Hinc in Embryone pene nullus vsus iecoris, vnde vena vmbilicalis iecur manifeste integra pertransit & à porta iecoris extat foramen vel anastomosis, vt sanguis regrediens ab intestinis fœtus; non per iecur, sed in dictam vmbilicalem transiens, cor (vna cum materno sanguine & reuertente à placenta vteri) petat, vnde etiam in prima fœtus conformatione iecur posterius fieri contingit, & nos etiam in fœtu humano obseruauimus perfecte delineata omnia membra, imo genitalia distincta, nondum tamen iecoris posita pene rudimenta. Et sane quousque membra (vt vel cor ipsum in initio) alba omnia apparent, & præterquam in venis nequidquam ruboris contineant, nihil præter rudem quasi extra venati sanguinis collectionem loco iecoris videbis, quam contusionem quandam vel raptam venam existimares.

Sed in ouo duo quasi vasa vmbilicalia, vnum ab albumine integrum pertransiens iecur & ad cor recte tendens, alterum à luteo in venã portam desinens: quippe contingit in ouo pullum primum ex albumine tantum formari & nutriri, à luteo vero post perfectionem & exclusionẽ (nam & intra intestina in ventre pulli contentum post multos dies ab exclusione potest luteum reperiri, & respondet luteum nutrimento lactis cæterorum animalium. sed hæc conuenientius in obseruationib. circa fœtus formationem, vbi huius generis possunt esse problemata plurima, cur hoc prius factum, aut perfectum sit, illud cur posterius? & de prin-

de principatu membrorum, quænam particula alterius causa sit? & circa cor plurima, vti cur primum (vt Arist. *de partibus animal.* 3) consistens factam sit? & habere videtur in se vitam, motum, & sensum, antequam quidquam reliqui corporis perfectum sit? Et similiter de sanguine quare antea omnia? & qualiter principiū vitæ & animalis habeat, & moueri atq; huc illuc impelli desiderat? cuius causa cor factū fuisse videretur.

Eodē modo in pulsuum speculatione, cur isti videlicet lethales aut contra & in omnibus generibus ipsorum causas & præsagia contemplando, quid isti significent, quid illud, & quare?

Similiter in Crisibus & expurgationibus naturæ, in nutritione, præsertim distributione alimenti similiter & omni fluxione.

Denique in omni parte medicinæ, Physiologica, Pathologica, Semiotica, Therapeutica, cum quot problemata determinari possunt ex hac data veritate & luce, quanta dubia solui, quot obscura dilucidari, animo mecum reputo: campum inuenio spatiosissimum, vbi longius percurre & latius expatiari adeo possim, vt non solum in volumen excrescceret præter institutum meum, hoc opus. Sed mihi forsan vita ad finem faciendum deficeret.

Hoc itaq; loco (*sequente videl. capitulo*) solūmodo, quæ in administranda Anatome circa fabricam cordis & arteriarum comparent, ad suos vsus & causas veras referre enitar, vt sicut quocunque me conuertam, plurima, quæ ex hac veritate lucem recipiant, & hanc vicissim illustriorem reddant, reperiuntur. Ita Anatomicis argumentis firmatam & exornatam p æ cæteris velim.

Est vnum quod licet inter obseruationes nostras de lenis vsu locum habere deberet, tamen hic quoq; obiter annotare non etit impertinēs. A Ramo splenico in pancreate deducto, è parte superiore venæ oriūtur coronalis, postica, gustrica, & Gastr œpiploica quę omnes plurimis furculis & ramificationibus in ventriculum (veluti meseraicæ in intestina) disseminantur. Similiter à parte inferiori illius splenici deorsum in colon & longanonem vsq; deducitur vena Hæmorrhoidalis, per has venas vtrinq; sanguis regrediens, & succū crudiorem secū hinc à ventriculo, aqueum, tenuem nondū perfecta Chilificatione; illinc crassum & terrestriorem, tanquā è fecibus, reportans in hoc ramo splenico, cōtrariorū permistione cōuenienter attēperatur, & ambos hos succos difficilioris coctionis (pp cōtrarios tamē in dispositiones) natura permiscēdo & multa copia calidioris sāguinis, à liene vbertime (pp multitudinē arteriarum)

riarum) ſcaturientis, ſuper infuſa; præparatos magis ad iecoris portus adducit, & defectum vtorumque extremorum tali venarum fabrica ſupplet & compenſat.

CAPVT XVII.

Confirmatur ſanguinis motus, & circuitus ex apparentibus in Corde, & ex iis, quæ ex diſſectione Anatomica patent.

COr non in omnibus animalibus inuenio diſtinctam eſſe, & ſeparatam particulam, alia enim (quaſi dicas) plant-animalia cor non habent, quia quædam animalia ſunt frigidiora, exiguæ corpulentiæ, mollioris texturę, ſimilaris cuiuſdam conſtitutionis, vt erucarum genus & Lumbricorum, & quæ exputredine oriuntur, non ſeruantia ſpeciem, plurima, iis cor non eſt vt quibus impulſore non opus ſit, quo alimentũ in extrema deferatur, corpus enim cõnatum & vnum abſque membris indiſtinctum habent, ſic vt contractione, & relatione totius corporis, intro ſumant & expellant, moueant & remoueant alimentum. Plant animalia dicta Oſtrea, Mytili, Spongie & Zoophytorum genera omnia, cor non habent, pro corde enim toto corpore vtuntur; & quaſi totum cor, huiuſmodi animal eſt.

In plurimis & pene omnibus inſectorum generibus, propter corpulentiæ exiguitatem diſcernere non poſſumus recte; attamen in apibus, muſcis, crabronibus, & huiuſmodi (aliquando ope perſpicilli) licet, pulſans quiddam intueri: etiam in pediculis, quibus tranſitus alimenti per inteſtina (cum translucidum ſit animal) quaſi maculam nigram cernere. inſuper clare poteris multiplicantis illius ſpecilli ope: ſed in exangnibus & frigidiotibus quibuſdam, vt cochleis, conchis, ſquillis, cruſtatis, his omnibus ineſt pulſans particula, (quaſi veſicula quædam vel auricula ſine corde) rarius vero contractionem & pulſum ſuum faciens, & quem non niſi æſtate, aut calidiori tempeſtate diſcernere liceat.

In his ita ſe habet iſta particula; impulſu aliquo opus eſt ad alimenti diſtributionem propter partium organicam varietatem aut denſitatem ſubſtantiæ: ſed rarius fiunt pulſationes, & quandoque non omnino, ob frigiditatem, prout conueniens illis eſt, quæ dubiæ ſunt naturæ, ita vt quando-

quandoque viuere, quandoque emori, videantur, & quandoque vitã animalis agere quandoque plantæ. Quod etiam inſectis videtur contingere (cum hyeme latent, & quaſi mortua occultantur) vel plantæ vitam tantummodo agant, ſed an idem etiam quibuſdam ſanguinis animalibus accidat, vt tanis, teſtudinibus, ſerpentibus, hirundinibus, non iniuria dubitare licet.

In animalibus vero maioribus, calidioribus, vtpote ſanguineis impulſore alimẽti, & cum vi forſan maiori, opus eſt: proinde vti piſcibus, ſerpentibus, lacertulis, teſtudinibus, ranis & huiuſmodi aliis, tum auricula, tum cordis ventriculus vnus, vnde & veriſſimum illud (Ariſtot. *de partibus animal.* 3.) quod nullum ſanguineum animal careat corde, quo impulſore validiora & robuſtiora, non ſolum ab auricula agitetur alimentum, ſed longius & celerius protrudatur.

Quin in adhuc maioribus, calidioribus & perfectioribus animalib. vtpote plurimo feruentiori & ſpirituoſo ſanguine abundãtibus quo protrudatur, fortius, celerius, & impetu maiori propter corporis magnitudinem, aut habitus denſitatem, alimentum, in his robuſtum cor magis & carnoſius deſideratur.

Et inſuper, quia perfectioribus, perfectiori opus alimento, & vberiori calore natiuo, vt alimentum concoquatur & vltetiorem perfectionem nanciſcatur, illis animalibus pulmones habere & alterum vẽtriculum, qui per ipſos pulmones alimentum trudat, conueniebat.

Sic quibuſcũque inſunt pulmones, vbi duo ventriculi cordis dexter & ſiniſter, & vbicunque dexter ibi ſiniſter quoque ineſt, non è contra vbi ſiniſter ibi dexter quoque (ſiniſtrum voco ventriculum vſu, non ſitu, diſtinctum videlicet, qui ſanguinem in totum corpus diffundat nõ in pulmones ſolum) hinc ſiniſter ventriculus per ſe cor efficere videtur, & in medio ſitus, ſcrobiculis altioribus ita inſculptus & maiori diligẽtia fabrefactus eſt, vt cor ſiniſtri ventriculi gratia factum videatur: & dexter ventriculus quaſi famuletur ſiniſtro, nec ad conum eius pertingit, & tenuiori triplo parietes eſt, & quaſi articularionem quandam (vt Ariſt.) ſupra ſiniſtrum habeat. Maiori capacitate vero vtpote, qui non ſolum ſiniſtro materiam, ſed & pulmonibus alimentum præbeat:

Notandum vero, quod in Embryone aliter ſe habent iſta, & non tãta differentia ſit ventriculorum, ſed tanquam in nuce nuclei gemelli, æqualiter pene ſe habent, & dexteri conus ad ſiniſtri ſummitatem pertingit, vt cor in his (tãquam duplici apice) in cono ſit, & hæc quoniam

in his (vt dixi) dum sanguis non transit per pulmones, vtique de dextro cordis sinu in sinistrum. Ambo per foramen ouale, & transitum arteriosum, vt dictum est, idem officium traducendi sanguinem è vena cava in arteriam magnam, pariter præstant, & in vniuersum corpus impellunt æqualiter, vnde æqualis constitutio. Cum vero pulmones vsui esse, & vniones dictas occludi, sit tempestiuum, tum hęc differentia ventriculorum incipit in robore, & reliquis esse; quia dexter duntaxat per pulmones, sinister per totum corpus impellit.

Vltra hæc etiam in corde lacertuli (vt ita dicam) siue carnosæ virgulæ, & fibrosi nexus plurimi (quos Aristot. *lib. de respirat. & de partibus animaliũ* 3. neruos vocat) qui partim separatim diuerso modo tenduntur; partim in parietibus & mediastino (altis factis scrobiculis) sulcatim recondititanquam musculi quidam parui. Qui ad robustiorem, & ad validiorem impulsum sanguinis, & constrictionem cordis quasi succéturiati sunt, & superadditi cordi, & ad vlteriorem expulsionem sanguinis auxiliatores, & vt (tanquam in nauisunium diligens & artificiosus apparatus) corde vndiquaque se contrahente, vndique adiumento forent; & sanguinem plenius & validius è ventriculis expellerent.

Hoc autem manifestum eo, quod quibusdam animalibus sint, quibusdam minime, & omnibus quibus sunt, illis plures & fortiores, sinistro, quam dextro, & quibusdam animalibus, in sinistro sunt, dextro vero nequaquam, & in hominum genere, plures in sinistro quam dextro ventriculo & plures in ventriculis quam auriculis, & aliquibus in auriculis quasi nulli. In Torosis & musculosis agrestibus corporibus, & duriorls habitus, plures; in tenellis corporibus fœminis pauciores.

In quibus animalibus ventriculi cordis intus leues; omnino absque fibris, lacertulis, neque scrobiculis fissi, (vt auibus minoribus pene omnibus, serpentibus, ranis, testudinibus, & huiusmodi, sic perdica, gallina, piscibus similiter maxima ex parte) in his neq; nerui (siue fibræ dictæ) neque valuulæ tricuspides in ventriculis reperiuntur. Quibusdam animalibus dexter ventriculus intus leuis est, sinister vero fibrosos illos nexus habet, vt in anſere, Cygno, & auibus grauioribus. In his eadẽ est ratio, quæ in omnibus; cum spõgiosi & rari & molles sint pulmones ad protrusionem sanguinis per ipsos, vim tantum non desiderari, proinde dextro ventriculo aut non sunt illæ fibræ, aut pauciores, infirmiores, non ita carnosæ, aut musculos æmulantes. Sinistri vero sunt & robustiores, & plures, & carnosiores, & musculosi, quia sinister ventriculus

maiori

maiori robore & vi opus habet, quo per vniuerſum corpus longius ſanguinem proſequi debuerat.

Et hinc etiam medium cordis poſſidet, & triplo craſſiori pariete, & robuſtiore eſt ſiniſter ventriculus dextro. Hinc omnia animalia, & inter homines ſimiliter, quo denſiori, duriori, & ſolidiori habitu ſunt carnis, & quo magis carnoſa, lacertoſa habent extrema membra, & magis a corde diſtantia: eo fibroſum, magis craſſum, robuſtum, & muſculoſum habent cor. Idque manifeſtum eſt, & neceſſarium. Quo contra rariori textura, & molliori ſunt habitu, & corpulentia minore, flaccidum magis, mollius, & intus minus (aut non omnino) fibroſum & enervatum cor gerunt.

Valuularum ſimiliter ſigmoidarum vſum conſidera; quæ ideo factæ, ne ſemel miſſus ſanguis in cordis ventriculos regeratur, & in orificio arterioſæ venæ & aortæ (dum ſurſum eleuatæ, & inuicem coniunctæ triquetram lineam, qualis ab hirundinum morſu relinquitur effingunt) quo arctius obſeruatæ, ſanguinis refluxum arceant.

Tricuſpides in introitu à vena caua, & arteria venoſa ianitores, ne cum maxime impellit ſanguis, retrolabatur, & ea de cauſa non inſunt omnibus animalibus (vt dixi) neq; quibus inſunt, eadem naturæ ſolertia factæ apparent, ſed in aliis exactius, in aliis remiſſius & negligentius, vt claudantur pro maiori vel minori impulſione à ventriculorum conſtrictione facta: Ideo in ſiniſtro ventriculo, vti ad maiorem impulſionem diligentior occluſio fiat: duo tantum ſunt inſtar mitræ, vt exactiſſime claudantur & longe in conum per medium pertingentes (quæ res impoſuit forſan Ariſtoteli vt hunc ventriculum duplicem ſectione per transuerſum facta exiſtimaret) ſimiliter profecto ne retro in arteriam venoſam labatur ſanguis, & exinde tobur ſiniſtri ventriculi exoluatur, in propellendo per vniuerſum corpus, ideo valuulæ iſtæ mitrales mole, & robore, & exacta clauſura, illas in dextro poſitas exuperant. Hinc etiã neceſſario nullũ cor ſine vẽtriculo cõſpicitur cũ lucanar & fons & prõptuariũ eſſe ſanguinis debeat: Idẽ vero in cerebro; nõ ſemper coringit. Auium n: genera pene omnia nullũ habẽt in cerebro ventriculũ, vt patet in anſere & cygno, quorũ cerebrũ cuniculi cerebro pene magnitudine æquatur. Cuniculi autẽ vẽtriculos, licet in cerebro habeãt, anſer tamẽ nõ habet. Similiter vbicunq; cordis vẽtriculus vnus, vna auricula appẽdit, flaccida, cuticularis, intus caua, ſanguine referta; vbi duo vẽtriculi, duæ ſimiliter auriculæ. Cõtra vero aliquib. auricula dũtaxat ineſt

animalibus (non autem cordis ventriculus) vel saltem vesica auriculæ analogon, vel vena ipsa in loco dilatata pulsum facit, vt videre in crabronibus, & apibus, & aliis insectis, quæ non solum pulsum habere, sed & respirationem in illa parte quam caudam nominant, experimentis quibus sū me posse demonstrare arbitror, (vnde ipsam elongare, & contrahere contingit modo frequentius, modo rarius, prout anhelosi magis videntur, & aere magis indigere) sed de his in tractatu de respiratione. Auriculas similiter pulsare aptum est, sese contrahere (vt ante dixi) & sanguinem in ventriculos coniicere, vnde vbicunque est ventriculus auricula necessaria non solum quod vulgo creditur, vt sit sanguinis receptaculum & promptuarium (quid enim opus est pulsatione ad retinendū) sed motores primi sunt sanguinis auriculæ, præsertim dextra, primum viuens, vltimum moriens (vt ante dictum est) quare necessaria, vt scilicet sanguinem in ventriculum subseruiens infundat. Qui vētriculus continuo (se ipsum contrahendo) iam ante in motu existentē sanguinem commodius elidat, & violentius propellat, vt cum ludas pila à reuerberatione fortius & longius percutiendo quam simplici et proiiciendo, impellere poteris. Quin etiam contra vulgarem opinionem, quia, neque cor, neque aliud quidquam seipsum distendere, sic potest, vt in seipsum attrahere sua diastole quicquam possit, nisi vt spōgia vi prius compressa, dum redit ad constitutionem suam, sed omnem motum localem in animalibus primum fieri, & principium sumpsisse constat à contractione alicuius particulæ: ideo à contractione auricularum coniicitur Sanguis in ventriculos vt ante patefeci, & inde à contractione ventriculorum proiicitur & transfertur.

Quæ veritas de motu locali, & quod immediatum organum motiuum in omni motu, omnium animalium in quo spiritus motiuus (vt Arist. dicit *libro de spiritu & alibi* primo in est) sit contractile, & quemadmodum νεῦρον à νεύω, nuto, contraho dicatur. Et quod Aristot. musculos cognouit, & non operam, omnem motum in animalibus retulit ad neruos siue ad contractile, & proinde illos lacertulos in corde neruos appellauit, si de motiuis organis animalium, & de musculorum fabrica ex obseruationibus nostris, quandoque demonstrare liceret, palam arbitrarer foret.

Quin institutum prosequentes, de auricularum vsu ad ventriculos implendos sanguine, vt ante demonstratum est; contingit; quo magis densum, compactum cor, pariete crassiore, eo auriculæ neruosiores & magis

magis muſculoſæ ad impellendum & implendum, quibus contra iis tanquam veſica ſanguinea, & membrana continens ſanguinem appareret (vt in piſcibus) (ibi enim tenuiſſima & adeo ampla eſt veſica, quæ auriculæ loco eſt, vt ſuper ipſam cor immntare videatur) vt in quib. piſcibus carnoſior paulo illa veſica eſt, perbelle pulmones æmulari & ementiri videtur; vt Cyprino & Barbo tinea & aliis.

In aliquibus hominibus toroſis videlicet, & duriores habitus dextrā auriculam ita robuſtam, & cum lacertulis, & vario fibrarum contextu interius affabre concinnatam reperi: vt aliorum ventriculos robore videretur æquipollere, & mirabar ſane in hominibus diuerſis, quanta eſſet differentia.

Sed notandum, quod in fœtu auriculæ longe maiores, quam pro proportione, quia inſunt, antequam cor fiat, aut ſuam functionem præſtat (vt ante demonſtratum eſt) & cordis ibi quaſi officium faciunt.

Sed quæ in formatione fœtus obſeruaui (& antea retuli, & Ariſtot. in ouo confirmat) maximam huic rei fidem & lucem afferunt. Interea dum fœtus, quaſi vermiculus mollis, & (vt dicitur) in iacte eſt, ineſt ſolum punctum ſanguineum, ſiue veſicula pulſans, & quaſi vmbilicalis venæ portio, in principio, vel baſi dilatata: poſtea cum fœtus delineatus, iam corpulentiam quandam duriorem habere incipit (iſta veſica carnoſior & robuſtior facta in auriculas (mutata conſtitutione) tranſit, ſuper quas cordis corpus pullulare incipit, (nondum vllum officium faciens publicum) formato vero fœtu, cum iam diſtincta oſſa à carnibus ſunt, & perfectum eſt animal, & motum habere ſentitur, tum cor quoque, intus pulſans habetur, & (vt dixi) vtroque ventriculo ſanguinem è vena caua in arteriam transfundit.

Sic natura perfecta & diuina nihil faciens fruſtra, nec cuipiam animali cor addidit, vbi non erat opus, neque priuſquam eſſet eius vſus fecit; ſed iiſdem gradibus in formatione cuiuſcunque animalis, tranſiens per omnium animalium conſtitutiones (vt ita dicam) ouum, vermem, fœtum, perfectionem in ſingulis acquirit. In fœtus formatione, multis obſeruationibus hæc alibi confirmanda ſunt.

Deniq; non immerito Hippocrates *in lib. de corde* ipſum muſculum nuncupauit, cum eadem actio, idem officium ſit, videlicet ſeipſum contrahere, aliud mouere, nempe contentum ſanguinem.

Inſuper ex fibrarum conſtitutione motiuaque fabrica vt in muſculis ipſis cordis actionem & vſum licet cernere, omnes Anatomici cum

Galeno annotarunt, cordis corpus vario fibrarum ductu videlicet recto, transuerso obliquo fabrefactum esse, at in corde elixo, aliter se habere deprehenditur fibrarum structura. Omnes enim fibræ in parietib. & septo circulares sunt, quales in sphincktere, illę vero quæ sunt in lacertulis, secundum longitudinem obliquæ, porrectæ: sic fit dum omnes fibræ simul contractæ sint, vt contingat, & conũ ad Basin à lacertulis adductum esse, & parietes in orbe circumclusas, & cor vndiq; contractũ esse & ventriculos coarctari, & proinde, cũ ipsius actio sit cõtractio, fũct onem eius esse sanguinem in arterias protrudere existimandum est.

Neq minus Aristoteli de principatu cordis assentiendum, an à cerebro motum & sensum accipiat? an à iecore sanguinem? an sit principium venarum, & sanguinis & huiusmodi? cum qui ipsum redarguere conantur, illud principale argumentum omittunt, aut non intelligunt, quod cor nempe primum subsistens sit, & habeat in se sanguinem, vitam, sensum, motum, antequam aut cerebrum aut iecur facta erant, vel plane distincta apparuerant, vel saltem vllam functionem edere potuerant. Et suis propriis organis ad motum fabricatis, cor, tanquam animal quoddam internum antiquius consistit. Quo primo facto, abipso postea fieri, nutriri, consetuari, perfici, totum animal, tanquam huius opus & domicilium, natura voluisset: & cor (tanquam in republ. princeps) penes quem primum & summum imperium vbique gubernans sit. A quo tanquam ab origine in animali, & à fundamento omnis potestas deriuetur, & dependeat.

At amplius circa arterias plurima similiter veritatem hanc illustrant & confirmant, cur arteria venosa non pulsat, cum numeretur inter arterias? aut cur in vena arteriosa pulsus sentitur? quia pulsus arteriarum sanguinis impulsio est.

Cur arteriæ in suæ tunicæ crassitie, & robore tantũ à venis differant, quia sustinent impetum impellentis cordis, & prorumpentis sanguinis.

Hinc cum natura perfecta nihil facit frustra; & in omnibus est sufficiens quanto arteriæ propinquiores cordi sunt, tanto magis à venis in constitutione differunt, & robustiores sunt, & ligamentosæ magis; in vltimis vero dissemination ibus ipsarum, vt manu, pede, cerebro, mesenterio, spermaticis ita constitutione similes sunt, vt ocularj tunicarum inspectione, alterum ab altero, internoscere difficile sit. Hoc autem iustis de causis sic se habet, nam quo longius arteriæ distant à corde, eo minore multo, vi, ab ictu cordis per multum spacium refracto, percelluntur.

luntur. Adde quod cordis impulſus, cum in omnibus arteriarum truncis, & ramulis ſufficiens ſanguini eſſe debuerat, ad diuiſiones ſingulas, quaſi partitus imminu tur.

Adeo vt vltimæ diuiſiones capillares, arterioſæ videantur venæ non ſolum conſtitutione, ſed & officio, cum ſenſibilem pulſum, aut nullem, aut non ſemper edunt, & niſi cum pulſat cor vehementius, aut arteriola in quauis particula dilatata; aut aperta magis ſit. Inde fit vt in dentibus quandoque & tuberculis, quandoque in digitis ſentire pulſum, quandoq; non poſſimus. Vnde pueros, quibus pulſus ſemper ſunt celeres & frequentes, hoc vno ſigno febricitare certo obſeruauerim, & ſimiliter in tenellis & delicatulis; ex compreſſione digitorum, quando febris in vigore eſſet, facile pulſu digitorum percipere potuerim.

Ex altera parte, quando cor languidius pulſat, non ſolum, non in digitis, ſed nec in carpo, aut temporibus pulſum ſentire contigit, vt in Lypothimia & hyſtericis ſymptomatib. & aſphyxia, debiliorib. morituris.

Hic ne decipiantur, monendi Chyrurgi, q̃ in ampuratione mẽbrorum & tumorum carnoſorum exciſione, & vulneribus; ſanguis cum vi proſiliens ſemper exit ab arteria, non autem ſemper cum ſaltu quia exiles arteriæ non pulſant, præſertim ſi ligatura compreſſæ fuerint.

Præterea cur vena arterioſa non ſolum arteriæ conſtitutionem, & tunicam habeat, ſed cur tam multum in craſſitie tunicæ non differat à venis, quam aorta, ratio eadem, maiorem à ſiniſtro ventriculo impulſum ſuſtinet aorta, quam illa à dextro & tanto mollioritunicarum conſtitutione, quam aorta eſt, quanto dexter ventriculus cordis & pariete, & carne ſiniſtro infi mior, & quanto pulmones in textura, & mollitie, ab habitu corporis & carnis recedunt, tantum differt venæ arterioſæ tunica, ab illa, quæ aortæ. Et ſemper hæc omnia vbique proportionem ſeruant, & in hominibus quanto magis toroſi, muſculoſi, & durioris ſunt hab.tus, & cor robuſtum, craſſum, denſum, & fibroſum magis, tanto & auriculas, & arterias proportionabiliter in omnibus reſpondentes craſſitie, robore habent.

Hinc quibus animalibus leues ventriculi cordis intus ſunt, abſque villis, aut valuulis, pariete tenuiore, vt piſcibus, auibus, ſerpentibus, & quam pluſimis generibus animalium, in illis arteriæ parum aut nihil à venis differunt in tunicarum craſſitie.

Amplius cur pulmones tam ampla habent vaſa, venam & arteriam, (vt truncus arteriæ venoſæ excedat vtroque ramos, crurales, &

iugu.a-

jugulares & cur tanti referti ſunt ſanguine, vt per experientiam & autopſiam ſcimus (monitu Ariſtot. non deceptiinſpectione eorum quos diſſectis detraximus animalibus, quorũ ſanguis totus effluxerit) cauſa eſt, quia inpulmonibus & corde promptuarium fons & theſaurus ſanguinis, & officina perfectionis eſt.

Cur ſimiliter arteriam venoſam, & ſiniſtrum ventriculum abundare videmus (in Anatomica diſſectione) tanta copia ſanguinis, & eiuſdem quidem, quo dexter ventriculus, & vena arterioſa replentur, ſimiliter nigricantis & grumeſcentis. Quoniam illinc huc continenter peragrat pulmones ſanguis.

Cur denique vena arterioſa dicta, vulgo conſtitutionem arteriæ; arteria venoſa venæ habeant. Quia reuera, & officio & conſtitutione & omnibus illa arteria, hæc vena ſit, contra quam vulgo creditur. Et cur vena arterioſa tam amplum habet orificium quia plus multi defert quam alendis pulmonibus ſit neceſſarium.

Hæc omnia phænomena inter diſſecandum obſeruanda, & plurima alia, ſi recte perpenſa fuerint, ante dictam veritatem, videntur luculenter illuſtrare & plane confirmare, ſimulque vulgaribus opinionibus aduerſari: eum quam ob cauſam ita conſtituta ſint, & facta hæc omnia difficile cuiquam admodum ſit, (niſi quo nos modo) explicare.

(?¿?)

FINIS.

Tot erratis, opusculo tam exiguo, lector benevole, exteriùs loci simpressio, absente authore & per tantum terræ matisque spatium diffito, his transmissioni epistolarum iniquis temporibus, rei nouitas & nostris correctoribus inusitata, missi exemplaris litera peregrina, veniam exposcunt. Reliqua minutiora facile inter legendum, hæc quæ & tuum intellectum impediant & authoris sensum peruertant, prius necesse est quam legas, (quod facillime poteris) penna corrigas.

Pag. 10. lin. 2. demonstratur quod quæ lege demonstratur, quæ, l. 9. quæ falsa dissectione † quæ falsa, dissectione lin. 15. manet † manat pag. 12. lin. 8. faueant † fouent. l. 14. attrahat † attrahantur l. 22. non merito † non immerito p. 13. l. 21. attrahuntur † contrahuntur p. 14. l. 15. per viam † peruiam l. 32. arteriæ † arterias. p. 15. l. 3. causis vti † causis quibus l. 30. negemus † negemus? p. 16. l. 3. sanguinis. † sanguinis? l. 7. publico. † publico? l. 11 cruralem, † cruralem) l. 15. habeat † habeat? l. 21. quod modo † quo modo l. 22. commeant. † commean: l. 29. egressi † regressui l. 31. sanguinis † sanguinis? p. 17. l. 26. transmitteret † transmitterent l. 5. affluerant. † affluerant? p. 18. l. 3. naturæ (& † naturæ & l. 7. laborant) † laborant p. 19. l. 9. expelli recensit, quinetiam † expelli: recensit quinetiam p. 20. l. 7. causa † causæ p. 22. l. 23. coloris † coloris p. 23. l. 6. ex allusione † ex allisione l. 33. omnes sunt † omnes fibræ sunt l. 34. vario † varie p. 24. l. 21. bronchia † branchias p. 25. lin. 21. missionem † immissionem l. 22. distentis † distendentis p. 26. l. 9 alteriorum † alterius l. 24. correspondere † correspondere p. 28. l. 18. revoluantur † revoluitur l. 22. lumacibus † limacibus p. 30. l. 5. Ritmo † Rithmo l. 6. fiant vnicus † fiant, & vnicus l. 13. deglutitione radicis, linguæ † deglutitione, radicis linguæ p. 31. l. 15. conspexisset † conspexissent p. 32. l. 1. Erisistratum † Erasistratum l. 7. quod hæc † quod has l. 9. ministerium illæ fuissent † ministerium fuissent 43. l. 4. anastomosim † anastemosim l. 17. postquam ingressum † postquam ingressus p. 35. l. 7. erectis † exactis l. 16. buccagine † beccagine p. 36. 24. intelligerent, siue † intelligerent:) siue p. 37. l. 19. vrettes † vreteres l. 26. nihilo † nihil p. 38. l. 8. coacti sint † coacti sunt l. 32. ossilla † oscilla p. 40. l. 34. compulsu † cum pulsu p. 41. l. 5. transmittat? dispensetur † transmittatur dispensetur l. 11. homines tantum † homines; tantum l. 33. à dextris † dextri l. 34. remeari † remeare p. 42. l. 4. æmulatus est † æmulari l. 5. condensant † condensantur l. 16. effatum † effætum l. 18. Microcosmi (vt † microcosmi vti l. 19. mentur) † meretur p. 34. l. 9. minium † minimum l. 5. esto scrupulum † esto ad scrupulum l. 22. proportione videlicet: subtripla, subsextupla, vel subo ctupla similiter proportio sanguinis exclusi debet esse ad ante contentum † proportione: videlicet subtripla subsextupla vel subo ctupla: similiter proportio sanguinis excluſa, debet esse ad ante contentam p. 44. l. 35. venis in arteriis † venis in arterias p. 45. l. 13. & toto † è toto l. 15. laniones laniones l. 17. reddunt in membrorum excisione & tumorum ex † reddunt: in membrorum excisione & tumorum, ex p. 46. l. 1. arteriis † arterias p. 48. l. 1. expulsus statim † exinde statim lin. 20. differentia † defrentia p. 49. l. 31. astu q. quodam † astu quasi quodam p. 50. l. 15. distendantur & pulsent † distenduntur & pulsant l. 31. suggerunt ita, quod, † suggerunt, ita quod p. 51. l. 4. ligatum corpus † ligatus carpus l. 23. mediocrem immissionem sanguinis per arterias & continuo † mediocrem, & immissionem sanguinis per arterias & continuo p. 52. l. 3. infractum † infarctum l. 8. colore † calore l. 12. supra ligaturam neque † supra ligatur: m, in cubito neque p. 53. l. 23. impulsio, sanguinis † impulsio sanguinis p. 54. l. 11. ô venis; necessarium est circuitum l. 16 aptari ore flexis † aptatis ore flexis p. 56. l. 4. varie cosos † varicosus l. 18. satis † sectis l. 22. elevati † elevatæ l. 31. modi † nodi p. 57. l. 26. progiedier te † pregredienti pag. 60. l. 22.

Tunc † tum p.61. l.26. cordialia roborat † cordialia roborant. l.18. incalescere vniuersum † in calescere incipit vniuersum l.29. Chelum † Chylum l.34. portum † portam l.35. cauam sic contingit † cauam, sic contingit l.36. consistenti, quæ † consistentia eodem, quæ p.62. l.28. raptam † ruptam l.18. anæstomosis † anastomosis p.63. l.9. illud † illi l.15. percurri † percurrere l.28. gustrica † gastrica, l.36. contrarios † contrarias p.64. l.1. portus † portas l.15. relatione † relaxatione l.25. cernere insuper † cernere insuper. p.5. l.46. sanguinis † sanguines l.12. validiora robustiora † validiore robustiore l.23. vbi † ibi p.66. l.16. nauifunium † naui funium l.17. corde cõtrahente † cordi contrahenti l.34. tantum † tantam l.36. sinustri † sinistro p.67. l.13. sigmoidarum vsum † sigmoidarum & tricuspidum vsum l.15. hirundinum † hirudinum l.16. obseruatæ † obseratæ l.18. impellit † impellitur l. 30. lucana † lacuna. p.67. l.29. exuperant. Hinc etiam (legeat si ita impressa fuissent exuperant. Hinc etiam l. 35. non habet. Similiter) lege ac si ita impressa non habet. similiter p.68. l.8. aptum † apertum l.17. simplici & † simpliciter l. 30. operam perperam p.69. l. 1. contrariis † contraiis l. 4. immutare videatur (vt quibus innatare videtur) & quibus l.6. tinca † tinea l. 7. duriores † durioris p.21. l. 37. vtroque † vtrosque p.71. l.1. tanti † tanto l.14. multi † multo.

HARVEY DEMONSTRATING TO CHARLES I. HIS THEORY OF THE CIRCULATION OF THE BLOOD

Painted by R. Hannah, engraved by H. Leman, published March 25, 1851, by Lloyd Bros. & Co., London

—From a copy in the State of Wisconsin General Hospital.

PART TWO

THE ENGLISH TRANSLATION

To The Moſt Illuſtrious and Indomitable Prince CHARLES, KING *of* GRE*A*T BRIT-*A*IN, FR*A*NCE *and* IRELA*N*D, DEFENDER *of the* F*A*ITH

MOST ILLUSTRIOUS PRINCE!

The heart of animals is the foundation of their life, the sovereign of everything within them, the sun of their microcosm, that upon which all growth depends, from which all power proceeds. The King, in like manner, is the foundation of his kingdom, the sun of the world around him, the heart of the republic, the fountain whence all power, all grace doth flow. What I have here written of the motions of the heart I am the more emboldened to present to your Majesty, according to the custom of the present age, because almost all things human are done after human examples, and many things in a King are after the pattern of the heart. The knowledge of his heart, therefore, will not be useless to a Prince, as embracing a kind of Divine example of his functions,—and it has still been usual with men to compare small things with great. Here, at all events, best of Princes, placed as you are on the pinnacle of human affairs, you may at once contemplate the prime mover in the body of man, and the emblem of your own sovereign power. Accept, therefore, with your wonted clemency, I most humbly beseech you, illustrious Prince, this, my new Treatise on the Heart; you, who are yourself the new light of this age, and, indeed, its very heart; a Prince abounding in virtue and in grace, and to whom we gladly refer all the blessings which England enjoys, all the pleasure we have in our lives.

Your Majesty's most devoted servant,

WILLIAM HARVEY

(London . . . . 1628.)

(TRANSLATION BY ROBERT WILLIS, M.D., 1847.)

To His Very Dear Friend
DOCTOR ARGENT

the excellent
and accomplished PRESIDENT *of* THE ROYAL COLLEGE *of* PHYSICIANS, *and* to other learned PHYSICIANS, his esteemed COLLEAGUES.

I have already and repeatedly presented you, my learned friends, with my new views of the motion and function of the heart, in my anatomical lectures; but having now for nine years and more confirmed these views by multiplied demonstrations in your presence, illustrated them by arguments, and freed them from the objections of the most learned and skilful anatomists, I at length yield to the requests, I might say entreaties, of many, and here present them for general consideration in this treatise.

Were not the work indeed presented through you, my learned friends, I should scarce hope that it could come out scatheless and complete; for you have in general been the faithful witnesses of almost all the instances from which I have either collected the truth or confuted error; you have seen my dissections, and at my demonstrations of all that I maintain to be objects of sense, you have been accustomed to stand by and bear me out with your testimony. And as this book alone declares the blood to course and revolve by a new route, very different from the ancient and beaten pathway trodden for so many ages, and illustrated by such a host of learned and distinguished men, I was greatly afraid lest I might be charged with presumption did

I lay my work before the public at home, or send it beyond seas for impression, unless I had first proposed its subject to you, had confirmed its conclusions by ocular demonstrations in your presence, had replied to your doubts and objections, and secured the assent and support of our distinguished President. For I was most intimately persuaded, that if I could make good my proposition before you and our College, illustrious by its numerous body of learned individuals, I had less to fear from others; I even ventured to hope that I should have the comfort of finding all that you had granted me in your sheer love of truth, conceded by others who were philosophers like yourselves. For true philosophers, who are only eager for truth and knowledge, never regard themselves as already so thoroughly informed, but that they welcome further information from whomsoever and from whencesoever it may come; nor are they so narrow-minded as to imagine any of the arts or sciences transmitted to us by the ancients, in such a state of forwardness or completeness, that nothing is left for the ingenuity and industry of others; very many, on the contrary, maintain that all we know is still infinitely less than all that still remains unknown; nor do philosophers pin their faith to others' precepts in such wise that they lose their liberty, and cease to give credence to the conclusions of their proper senses. Neither do they swear such fealty to their mistress Antiquity, that they openly, and in sight of all, deny and desert their friend Truth. But even as they see that the credulous and vain are disposed at the first blush to accept and to believe everything that is proposed to them, so do they observe that the dull and unintellectual are indisposed to see what lies before their eyes, and even to deny the light of the noonday sun. They teach us in our course of philosophy as sedulously to avoid the fables of the poets and the fancies of the vulgar, as the false conclusions of the sceptics. And then the studious, and good, and true, never suffer their minds to be warped by the passions of hatred and envy, which unfit men duly to weigh the arguments that are advanced in behalf of truth, or to appreciate the proposition that is even

fairly demonstrated; neither do they think it unworthy of them to change their opinion if truth and undoubted demonstration require them so to do; nor do they esteem it discreditable to desert error, though sanctioned by the highest antiquity; for they know full well that to err, to be deceived, is human; that many things are discovered by accident, and that many may be learned indifferently from any quarter, by an old man from a youth, by a person of understanding from one of inferior capacity.

My dear colleagues, I had no purpose to swell this treatise into a large volume by quoting the names and writings of anatomists, or to make a parade of the strength of my memory, the extent of my reading, and the amount of my pains; because I profess both to learn and to teach anatomy, not from books but from dissections; not from the positions of philosophers but from the fabric of nature; and then because I do not think it right or proper to strive to take from the ancients any honour that is their due, nor yet to dispute with the moderns, and enter into controversy with those who have excelled in anatomy and been my teachers, I would not charge with wilful falsehood any one who was sincerely anxious for truth, nor lay it to any one's door as a crime that he had fallen into error. I avow myself the partisan of truth alone; and I can indeed say that I have used all my endeavours, bestowed all my pains on an attempt to produce something that should be agreeable to the good, profitable to the learned, and useful to letters.

Farewell, most worthy Doctors,

And think kindly of your Anatomist,

William Harvey.

(Translation by Robert Willis, M.D., 1847.)

Introduction

IN DISCUSSING the movements and functions of the heart and arteries, we should first consider what others have said on these matters, and what the common and traditional viewpoint is. Then by anatomical study, repeated experiment, and careful observation, we may confirm what is correctly stated, but what is false make right.

Nearly all anatomists, physicians, and philosophers up to now have thought with Galen that the pulse has the same function as respiration, differing only in one respect, the former arising from an animal, the latter a vital faculty, but from the standpoint of function or movement behaving alike. Thus one finds, as in the recent book on *Respiration* by Hieronymus Fabricius of Aquapendente, that since the pulsation of the heart and arteries is not sufficient for the aeration and cooling of the blood, Nature has placed the lungs around the heart. So it seems that whatever has been said prior to this about the systole and diastole of the heart and arteries has been proposed with special reference to the lungs.

Since the movements and structure of the heart differ from those of the lungs, as those of the arteries from those of the chest, separate functions or purposes are likely. The pulsings and uses of the heart as well as of the arteries are distinct from those of the chest and lungs. If the pulse and respiration have the same purpose, if the arteries in diastole draw air into their cavities (as commonly said) and in systole give off waste vapors by the same pores in flesh and skin, and if also in the time between systole and diastole they contain air,[1] in fact containing at all times either air, spirits, or sooty vapors, what may be answered to Galen? He declared that the arteries by nature contain blood and blood alone, neither air nor spirits, as may easily be determined by experiments and explanations found in his report.

If in diastole the arteries are filled by air drawn in, the greater the pulse the greater being the amount drawn in, then when the whole body is immersed in a bath of oil or water, a previously strong pulse should either become much weaker or slower, for the bath surrounding the body will make it difficult if not impossible for the air to enter the arteries. Likewise, when all the arteries, the deep as well as

[1] The word *fuligines* is translated *waste-vapors*. The idea of this supposed *sooty material* may have developed from the duskier hue of venous blood. The intake and output of air to and from the arteries through pores in flesh and skin goes right back to Empedocles (5th Cent. B.C.). Interesting that this should be involved in the first aspect of current opinion about the heart and blood-vessels to be refuted by Harvey.

superficial, are distended at the same time and with equal speed, how is it possible for the air to penetrate as easily and quickly through the skin, flesh, and bulk of the body to the deeper parts as through the skin alone? How may the arteries of the fetus draw air into their cavities through the mother's abdomen and the uterine mass? How may seals, whales, dolphins, other species of cetaceans, and all kinds of fish in the depths of the sea draw in and give off air through the great mass of water by the pulsing systole and diastole of their arteries? To say that they absorb air fixed in the water and give off their waste vapors to the water is pure fiction.[2]

If the arteries during systole exhale waste vapors from their cavities through the pores of the flesh and skin, why not at the same time the spirits said to be contained within them, for spirits are much more volatile than sooty wastes. Again, if the arteries receive and pour out air in diastole and systole, as the lungs in respiration, why not the same if cut open as in arteriotomy? In cutting open the trachea it is clear that the air goes in and comes out of the

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[2] Of course this is just what they do. The fundamental facts about respiration were established by A-L. Lavoisier (Hist. Acad. roy. d. Sci., Paris, 1784, p. 355) and, for internal respiration, by G. Magnus (Ann. Phys. u. Chem., 1837, 41: 583). The fundamental laws about gaseous behavior were being developed about 1660 by Robert Boyle (1627–1691), but I have not been able to find who first showed the solubility of air in water. The laws governing these phenomena were studied by Henry in 1803 and by Dalton in 1807. Humboldt and Provencal first studied the respiration of fishes (Mem. Soc. phys. chim. d'Arcueil, Paris, 1807, 2: 359).

wound in two opposite directions. In cutting open an artery it is equally clear that the blood escapes in one continuous direction and that no air either goes in or comes out.

If the pulsations of the arteries cool and purify the various portions of the body as the lungs do the heart, how, as is commonly said, do the arteries carry from the heart to the separate parts the vital blood stuffed with vital spirits, which keep up the heat of these parts, nourish them in sleep, and restore them in exhaustion? How, if the arteries be tied off, do the parts at once become not only torpid, cold, and pale, but even cease to be nourished, unless it be as Galen says that they have been deprived of that heat which flowed through them from the heart? So it would seem that the arteries carry heat to the parts instead of cooling them.

Now, how may the diastole draw spirits from the heart to warm the parts at the same time from the outside to cool them? Further, although some state that the lungs, arteries, and heart have the same function, they also say that the heart is the factory of the spirits and that the arteries contain and transmit them, denying, contrary to the opinion of Columbus,[3] that the lungs either make or contain

[3] Not Christopher but Matheus Realdus (1516–1559). A vain, unscholarly, and unscrupulous man, pupil of Vesalius, and Professor of Anatomy at Rome. In his *De Re Anatomica* (1559), he correctly described the pulmonary circulation, but failed to realize the significance of what he did. He made a distinct advance over the Galenists, however, in thinking that blood was rendered "spiritous" by air in

spirits. Then they declare with Galen that blood is contained in the arteries, and not spirits, contrary to Erasistratus.

It is clear that these opinions are so contradictory and irreconcilable that all are doubtful. Blood is to be found in arteries, and blood alone, as is plain from the experiment of Galen, from arteriotomy, and from wounds. By cutting open a single artery, as Galen states more than once, all the blood may easily be drained from the whole body in a half hour's time. The experiment of Galen referred to is this: "If you will place two ligatures around an artery and make a longitudinal incision in the portion of the artery between them, nothing but blood will be found." Thus does he prove the arteries contain blood alone. We may reason similarly. Finding the same blood in veins, tied off in a similar manner, that is found in arteries (as I have frequently noted in dead and living animals), we may

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the lungs instead of in the heart. Foster thinks (Hist. of Physiol., 1901, p. 30) he cribbed the description from the unfortunate religious fanatic, Michael Servetus (1510–1553), who was burned under Calvin at Geneva. The latter's *Restitutio Christianismi* (1553) contains a remarkable passage discussing the pulmonary circulation, but since only 3 copies escaped the flames, it obviously could have little influence. Servetus had studied anatomy in Paris with Vesalius. Galen (131–201 A.D.) showed that arteries contained blood, contrary to the opinion of the earlier Greeks, as exemplified by Erasistratus of Alexandria (3rd Century B.C.) who found the arteries empty in dissections of dead bodies. Harvey discusses all these points later.

I have broken into shorter paragraphs, for greater ease in reading, a couple of very long paragraphs through here in the original.

likewise conclude that arteries contain the same blood as veins and nothing but the same blood.[4]

Some authors, while trying to explain this difficulty in saying that blood is spiritous in the arteries, tacitly allow that the function of the arteries is to distribute the blood from the heart to the whole body, and that the arteries are filled with blood. Spiritous blood is none the less blood, as no-one denies that the blood, even that which flows in the veins, is filled with spirits. Even if the blood in the arteries is very gorged with spirits, it is still believable that these spirits are as inseparable from the blood as those in the veins. The blood and spirits comprise a single fluid (as whey and cream in milk, or heat in hot water) with which the arteries are filled, and for the distributing of which from the heart the arteries exist. This is nothing else than blood.

If this blood is drawn from the heart into the arteries by their diastole it follows that the arteries in their distention are filled with blood, and not with air, as previously discussed. If they are said also to be filled from the surrounding atmosphere,

[4] Harvey was philosophically interested in the ideas about the origin and "perfection" of blood. Not being able to find "spirits" anywhere, he is apparently trying to show that arteries as well as veins contain the same fundamental fluid, blood,—and that there is no "vital" difference between arterial or venous blood. See next paragraph. The chemical difference between arterial and venous blood was demonstrated in 1668 by John Mayow (1643–1679), but due to Stahl's phlogiston theory, his ideas were neglected until they developed through Lavoisier and Magnus, note 2.

how and when do they take in blood from the heart? During systole is impossible: the arteries would have to fill while contracted, or to fill and not become distended. During diastole is improbable: they would then receive for two contrary purposes both blood and air, and heat and cold.

Further, when it is stated that the diastole of the heart and arteries is simultaneous, and the systole likewise, there is another inconsistency. How can two bodies being connected together and being distended at the same time draw anything one from the other? Or being contracted simultaneously receive anything one from the other? Moreover, it seems impossible that one body may thus draw another body to itself in order to become distended, since distention is passive, unless return is made to a natural state, like a sponge previously compressed by external force. It is hard to imagine anything like this in the arteries.

The arteries distend because they are filled like bladders or pouches and they are not filled because they expand like a bellows, as I have easily and clearly shown, and proved, I think, ere this. However, in Galen's book, *Quod sang. cont. in Arter.*, there is an experiment to show the opposite: an artery is exposed and cut longitudinally, and a reed or hollow tube is inserted through the opening, so the wound is closed and the blood not driven out. "As long as it stays thus," he says, "the whole artery will pulsate, but if you tie a thread around

the artery firmly pressing its tunics against the tube you will see the artery does not beat as fully beyond the noose." I have neither made this experiment of Galen's, nor do I believe it can be done easily in the living body because of the excessive loss of blood from the artery. I doubt that the tube would close up the wound without a ligature, and that blood would not burst out between the tube and the vessel. Yet Galen seems to prove[5] by this experiment both that the pulsating power passes from the heart through the walls of the arteries, and that the arteries while dilating are filled by this pulsating power since they dilate like a bellows and do not distend because they are filled like a leather bottle.

The contrary, however, is apparent in arteriotomy and wounds, the blood leaping from the artery rushes out with force, first farther, then nearer, alternately in spurts, the spurt being always during the distention of the artery, never during its contracture. From this it is obvious that the artery is distended by the impulse of blood, for it is impossible for it *per se* to throw the blood with such force while dilating,—it should rather be drawing air into itself through the wound, according to the common ideas on the functions of the arteries.

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[5] A little unfair to Galen (131-201 A.D.). Not only was the experiment not tried, but unwarranted conclusions are unjustly ascribed to him. This simile of the bellows and leather bottle is frequently used by Harvey.

We should not let the thickness of the arterial walls mislead us into believing that the pulsating power moves along them from the heart.[6] In some animals the arteries do not differ from the veins, and in the distant parts of the body where the arteries are finely divided, as in the brain and hand, no-one can tell arteries from veins by their walls, for the tunics are the same in both. In an aneurysm arising from an injured or eroded artery, the pulse is just the same as in the other arteries, but it has no arterial tunic. The renowned Riolan supports me in this in his 7th Book.

It is not to be supposed that the function of the pulse is the same as that of respiration because the respiration is made more frequent and powerful, as Galen says, by the same causes as running, bathing or any other heating agent. Not only is experience opposed to this (though Galen strives to get around it), when by immoderate gorging the pulse becomes great and the respiration less, but in children the pulse is rapid when respiration is slow. Likewise in fear, trouble, or worry, in many fevers, of course, the pulse is very fast, the respiration slower than usual.

[6] As in a peristaltic wave. The elasticity of blood-vessel walls, depending on their elastic fibers and smooth muscle tunics, is now recognized as a factor in maintaining blood pressure. Harvey demonstrated that the pulsation in the arteries is due to their sudden distention by blood forced out of the heart during its contraction. Andreas Caesalpinus (1519–1603) argued this point in his *Quaestiones Peripateticae* (Lib. V, Quaest. 4) in 1571, but without apparently impressing any of the anatomical or medical investigators of his or the next century.

These and other similar inconveniences beset the traditional opinions about the pulse and the functions of the arteries. Those maintained on the function and beat of the heart are perhaps no less involved in many tangled difficulties. The heart is commonly said to be the source and factory of the vital spirits, from which life is given to the different portions of the body, yet that the right ventricle makes spirits is denied,—it merely gives nourishment to the lungs. So it is said that the right ventricle of the heart is lacking in fishes (indeed in all animals in which there are no lungs), and that the right ventricle exists for the sake of the lungs.

1. The structure of both ventricles is practically the same. There is the same fabric of fibers, braces, valves, vessels, auricles, and both on section are filled with similar dark colored and coagulated blood. Why, then, should we imagine their functions to be so different when the action, movement, and beat of both are the same? The three tricuspid valves at the entrance to the right ventricle are a hindrance to the return of blood into the vena cava. The three semilunar valves at the opening of the pulmonary artery are placed to prevent back flow of blood. Why, then, when there are similar structures in the left ventricle, should we deny them a similar purpose, of hindering at one place the escape, at the other the reflux of the blood?

2. When the size, shape, and position of these structures are almost the same in the left ventricle

as in the right, why say they are for the purpose of impeding the escape and reflux of spirits in the left ventricle but of blood in the right? The same arrangement cannot be suited to hinder in a similar way blood as well as spirits.

3. When the openings and vessels mutually correspond in size, as is clear in the pulmonary artery and pulmonary vein,[7] why should one have a particular function, viz., of nourishing the lungs, but the other a general function?

4. How is it possible (as Realdus Columbus notes) that so much blood is needed for the nourishment of the lungs, with the pulmonary artery leading to them exceeding in size both iliac veins?

5. Again I ask, when the lungs are so near, the blood vessel to them of such size, and themselves in continual motion, what is the object of the beat of the right ventricle? And why did Nature have to add this other ventricle to the heart for the sake of nourishing the lungs?

It is said that the left ventricle draws material for forming spirits, namely air and blood, from

[7] These terms in the Latin are confusing. The pulmonary artery was called *vena arteriosa*, "the vein similar to an artery." A "vein," because it carried "natural spirits" to nourish the lung, but its structure was recognized to be like that of the aorta, or great artery. The pulmonary vein was called *arteria venosa*, "the artery similar to a vein." An "artery" because it carried "vital spirits" (and many other things, as Harvey shows, in opposite directions!), but its structure was admittedly venous. It is not always easy to keep these terms straight. Even Dr. Robert Willis, whose splendid translation of Harvey for the Sydenham Society (1847) is the standard English version, slipped.

the lungs and right cavity of the heart. Likewise it sends spiritous blood into the aorta. From this it separates waste-vapors which are released to the lung by the pulmonary artery. From the lung spirits are obtained for the aorta. How is this separation made? How do spirits and waste-vapors pass here and there without mixture or confusion? If the mitral valves[8] do not stop the passage of waste vapor to the lungs, how do they stop the escape of air? How do the semilunars prevent the return of spirits from the aorta following cardiac diastole? Above all, how can it be said that the pulmonary vein distributes the spiritous blood from the left ventricle to the lungs without hindrance from the mitral valves, having asserted that air enters the left ventricle from the lungs by this same vessel and is prevented from going back to the lungs by these same mitrals? Good God! How do the mitral valves prevent escape of air and not of blood?

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[8] These are referred to as *tricuspides mitrales*, and later in this same paragraph simply as *tricuspides*. The tricuspids and mitral valves are described in Chapter XVII, but not specifically differentiated by name. The specific terminology became established within the next century. Thus William Cheselden (1688–1752), in his *Anatomy of the Human Body*, 1713, says, "Over the entrance of the auricles in each ventricle, are placed valves to hinder a return of blood when the heart contracts. Those in the right ventricle are named Tricuspides, those in the left Mitrales." Harvey was not the first to use the term "mitral." Vesalius (1514–1564) was apparently the first to compare the left auriculo-ventricular valves to an episcopal miter. The best publication on the heart after Harvey's is Richard Lower's (1631–1690) *Tractatus de Corde* (1669). In this he specifically and consistently refers to the "mitral valves."

Further, if the pulmonary artery, a large vessel, with heavy arterial walls, be destined for only the single particular purpose of nourishing the lungs, why should the pulmonary vein, scarcely of the same size, with soft flabby venous walls, be supposed to have three or four different uses? It is desired that air pass through this vessel from the lungs to the left ventricle, likewise that waste vapors escape by the same vessel from the heart to the lungs, and that some of the spiritous blood from the heart be distributed by it to keep the lungs alive.

To desire that waste vapors from the heart and air to the heart be transmitted by this same conduit is opposed to Nature which nowhere has made but a single vessel or way for such contrary movements and purposes.

If waste vapors and air come and go by this passage, as they do in the pulmonary bronchi, why do we find neither air nor sooty vapors when we cut open the pulmonary vein? Why do we always find the pulmonary vein full of thick blood, never of air, while in the lungs we note plenty of air?

If one repeats Galen's experiment of opening the trachea of a living dog, forcing air into the lungs by a bellows, and then firmly tying off the trachea, a great abundance of air even out to the pleurae will be found in the lungs on opening the chest. No air, however, will be found in the pulmonary vein or in the left ventricle of the heart. It certainly should be if the heart drew in air from the lungs, or if the

lungs transmitted air to the heart, in the living dog. On inflating the lungs of a cadaver in an anatomical demonstration, who doubts the air could be seen going this way if such a passage exists? This function of the pulmonary vein, the transmission of air from the lungs to the heart, is considered so significant that Hieronymus Fabricius of Aquapendente insists the lungs were made for the sake of this vessel[9] and that it is their most important structure.

I would like to know why the pulmonary vein is built like a vein if it is destined for the transmission of air.

It would be more natural for it to be made of ringed tubes such as those of the bronchi, in order always to be open and not liable to collapse. Thus it might remain free from blood with no liquid to hinder the passage of air, as may sometimes be noted in the lungs when they labor under more or less phlegm in the bronchi, when breathing is sibilant or strepitous.

Even less tolerable is the opinion which supposes two materials, air and blood, necessary for the formation of vital spirits. The blood is supposed to ooze through tiny pores in the septum of the heart from the right to the left ventricle, while the air is drawn from the lungs by the large pulmonary vein. Accord-

[9] Not quite as respectful of Fabricius (1537–1619) as one would expect in a devoted pupil. For a translation of the passage referred to (*De Respiratione*, 1603), see M. Foster's famous History of Physiology, Cambridge, 1901, p. 38.

ing to this many little openings exist in the septum of the heart suited to the passage of blood. But, damn it, no such pores exist, nor can they be demonstrated!

The septum of the heart is of denser and more compact material than any part of the body except bones and tendons. Even so, supposing the pores are there, how could the left ventricle draw blood from the right when both ventricles contract and dilate at the same time? Why not rather believe that the right ventricle draws spirits through these pores from the left instead of the left ventricle drawing blood from the right? It is surely miraculous and incongruous that plenty of blood should be drawn through obscure invisible openings in the same time as air through wide open ones. Why require invisible pores and obscure uncertain channels to get the blood to the left ventricle when there is such a wide open passage through the pulmonary vein? It is certainly remarkable that a way had to be made, or rather invented, through the dense, tough, and compact septum of the heart, instead of through the open pulmonary vein, and the soft spongy mass of the lungs. If the blood can permeate the material of the septum, or be imbibed from the ventricles, what is the use of the coronary arteries and veins, branches of which go to the septum itself, for its nourishment? Specially noteworthy is this: if in the fetus, where everything is softer and more lax, Nature had to bring the blood to the

left ventricle by the foramen ovale, from the vena cava through the pulmonary vein, how is it likely in the adult to pass so plentiously and with no effort through the cardiac septum, now denser with age?

On the authority of Galen (*de loc. affect. lib. 6, cap. 7*), and the experience of Hollerius, Andreas Laurentius (*lib. 9, cap. 11, questione 12*) asserts that the serum and pus in empyema, absorbed from the thoracic cavity into the pulmonary vein, can be eliminated through the left ventricle of the heart and the arteries in the urine and feces. As evidence he cites a certain case of melancholy, who suffering from fainting spells, was relieved from the seizures by voiding some turbid and fetid urine. Worn out by the disease he finally died. On opening the body none of the material he excreted was found in the bladder or kidneys. In the left heart, however, and in the thoracic cavity, there was much of it, and Laurentius boasts he predicted the cause of the symptoms. I wonder, since he predicted that such conglomerate material was evacuated as indicated,[10] why he could not, or would not discern that the blood is naturally carried from the lungs to the left ventricle in the same way.

From these and many other considerations it is clear that what has so far been said on the movement

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[10] How much of this is sarcasm against the pathology? Jacob Hollerius lived between 1498 and 1562. Andreas Laurentius (1550–1609) migrated from Montpellier to Paris, and although physician to Henry IV, was considered an ignorant man.

and function of the heart and arteries must seem obscure, inconsistent, or impossible to the thoughtful student. It will therefore be proper to investigate the matter more closely, to study the movement of the heart and arteries not only in man but in all animals possessing a heart, and to search out and find the truth by frequent experiments in living animals, and by constant observation.

Chapter I

The Author's Reasons for Writing

WHEN I first tried animal experimentation for the purpose of discovering the motions and functions of the heart by actual inspection and not by other people's books, I found it so truly difficult that I almost believed with Fracastorius,[1] that the motion of the heart was to be understood by God alone. I could not really tell when systole or diastole took place, or when and where dilatation or constriction occurred, because of the quickness of the movement. In many animals this takes place in the twinkling of an eye, like a flash of lightning. Systole seemed at one time here, diastole there, then all reversed, varied and confused. So I could reach no decision, neither about what I might conclude myself nor believe from others. I did not marvel that Andreas Laurentius wrote that the motion of the heart was as perplexing as the flux and reflux of Euripus[2] was to Aristotle.

[1] *De sympathia et antipathia, Cap. 15, Opera Omnia,* Venice, 1555 p. 95. H. Fracastorius (1484–1553) was the author of the famous poem which gave the name to the disease syphilis, *Lib. Tres Syphilidis, sive Morbi Gallici* (1530).

[2] A narrow channel 113 miles long, between Euboea and Boeotia, opposite Chalcis, renowned in antiquity for the violent flow and reflow of its tide.

Finally, using greater care every day, with very frequent experimentation, observing a variety of animals, and comparing many observations, I felt my way out of this labyrinth, and gained accurate information, which I desired, of the motions and functions of the heart and arteries. From that time I have not hesitated to declare my thoughts on this matter, not only in private to friends, but even publicly in my anatomical lectures, as in the ancient Academy.

As usual, these views pleased some, not others. Some blamed me of wrong in daring to depart from the precepts and faith of all anatomists. Others wanted more information on these new ideas which were thought worthy of interest and of possible value. Finally I have consented to the requests of friends, that anyone may be made acquainted with my work. I have also been moved by the envy of some who, receiving my words blindly and with no understanding, have tried to ridicule me in public. So I have decided to publish my findings so all may form an opinion of me and of the work itself. I am pleased to do this since Hieronymus Fabricius of Aquapendente, although he has correctly and in a scholarly manner described almost all the parts of animals, has not discussed the heart.

Finally, if my work may be helpful to this phase of literature, it may perhaps be granted that I have not lived idly. As the old man in the comedy says:[3]

[3] Terrence, in *Adelphi*, Act V, Sc. IV, 1 (Demea). Harvey quotes the Latin quite correctly. My unsatisfactory translation of the four

None age so perfectly that subtle change
With time or custom seems not new nor strange;
What's once believed is now denied, and what
Was honored once now suffers in exchange.

So may it now be regarding the motion of the heart. The path is open for others, starting here, to progress more fortunately and more correctly under a more propitious genius.

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lines may be excused on the plea that it places the context in the appropriately tolerant and resigned verse-form made famous by Edward FitzGerald. Dr. Willis, in his 1847 Harvey, translates the lines in the classical tradition:

For never yet hath any one attained
To such perfection, but that time, and place,
And use, have brought addition to his knowledge;
Or made correction, or admonished him
That he was ignorant of much which he
Had thought he knew; or led him to reject
What he had once esteemed of highest price.

George Colman's translation is quoted by T. B. Harbottle, Dictionary of Quotations (Classical), London and New York, 1897.

Chapter II

The Motions of the Heart as Observed in Animal Experiments

IN THE first place, when the chest of a living animal is opened, and the capsule surrounding the heart is cut away,[1] one may see that the heart alternates in movement and rest. There is a time when it moves, and a time when it is quiet.

This is more easily seen in the hearts of cold-blooded animals, as toads, snakes, frogs, snails, shell-fish, crustaceans, and fish. It is also more apparent in other animals as the dog and pig, if one carefully observes the heart as it moves more slowly when about to die. The movements then become slower and weaker and the pauses longer, so that it is easy to see what the motion really is and how made. During a pause, the heart is soft, flaccid, exhausted, as in death.

Three significant features are to be noted in the motion and in the period of movement:

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[1] The only reference to the pericardium made by Harvey. The idea that it prevents overdistention of the heart probably never occurred to him. For current ideas on the function of the pericardium see J. A. Wilson and W. J. Meek, Amer. J. Physiol., 82: 34 (Sept.) 1927.

1. The heart is lifted, and rises up to the apex, so that it strikes the chest at that moment, and the beat may be felt on the outside.[2]

2. It contracts all over, but particularly to the sides, so that it looks narrower and longer. An isolated eel's heart placed on a table or in the hand shows this well, but it may also be seen in the hearts of fishes and of cold-blooded animals in which the heart is conical or lengthened.

3. Grasping the heart in the hand, it feels harder when it moves. This hardness is due to tension, as when one grasps the fore-arm and feels its tendons become knotty when the fingers are moved.

4. An additional point may be noted in fishes and cold-blooded animals, as serpents and frogs. When the heart moves it is paler in color, but when it pauses it is of a deeper blood color.

[2] The first clear statement of the significance of the apex beat. In the physiological analysis of the events of the cardiac cycle in an intact subject, this is an important reference point, marking, as Harvey noted, the moment of ventricular systole and emptying. The graphic analysis of the cardiac cycle was especially developed by E. J. Marey (1830–1904), *La Circulation du Sang*, Paris, 1881, and was made possible by the methods of recording by kymograph initiated by Carl Ludwig (1816–1895).

This is the first of that remarkable series of extraordinarily acute observations on the motion of the heart and blood so simply and clearly reported by Harvey in this book. Compare the number and quality of these observations and the clear interpretation of their significance as made by him, with the stumbling, vague, and incomplete ideas on the matter as given by Servetus (1510–1553), Columbus (1516–1559), Ruini (died before 1598), Caesalpinus (1524–1603), and others for whom credit is claimed for discovering the circulation, and you will agree that to Harvey alone should be given the honor of first realizing the full truth, and of demonstrating it to the world.

From these facts it seems clear to me that the motion of the heart consists of a tightening all over, both contraction along the fibers, and constriction everywhere. In its movement it becomes erect, hard, and smaller. The motion is just the same as that of muscles when contracting along their tendons and fibers. The muscles in action become tense and tough, and lose their softness in becoming hard, while they thicken and stand out.[3] The heart acts similarly.

From these points it is reasonable to conclude that the heart at the moment it acts, becomes constricted all over, thicker in its walls and smaller in its ventricles, in order to expel its content of blood. This is clear from the fourth observation above in which it was noted that the heart becomes pale when it squeezes the blood out during contraction, but when quiet in relaxation the deep blood red color returns as the ventricle fills again with blood. But

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[3] Niels Stensen (1638–1686), the Danish anatomist who later became a bishop of the Roman church, is usually credited with recognizing the muscular character of the heart (*De Musculis et Glandulis Observationum Specimen*, 1664). This is a little unfair to Harvey, and, for that matter, to the unknown author of the Hippocratic tract on the heart to which Harvey refers in Chapter XVII. Stensen, as far as I can determine, did little more than these in comparing the heart's contraction to that of a muscle, and then saying that it is nothing more than muscle. The structural (histological) similarity between the heart and muscle was shown in A. Leeuwenhoek's (1632–1723) *Arcana Naturae* (Delft, 1695), in which *Epistola 82* (page 445) gives the first clear account of the peculiar structure of cardiac muscle, with excellent illustrations. For an interesting account of Stensen, see Dr. W. S. Miller's paper, Johns Hopkins Hosp. Bull., 25: 44 (Feb.) 1914.

no one need doubt further, for if the cavity of the ventricle be cut into, the blood contained therein will be forcibly squirted out when the heart is tense with each movement or beat.

The following things take place, then, simultaneously: the contraction of the heart; the beat at the apex against the chest, which may be felt outside; the thickening of the walls; and the forcible ejection of the blood it contains by the constriction of the ventricles.

So the opposite of the commonly received opinion seems true. Instead of the heart opening its ventricles and filling with blood at the moment it strikes the chest and its beat is felt on the outside, the contrary takes place so that the heart while contracting empties. Therefore the motion commonly thought the diastole of the heart is really the systole, and the significant movement of the heart is not the diastole but the systole. The heart does not act in diastole but in systole for only when it contracts is it active.

It is not to be admitted that the heart moves only in the direction of its straight fibers. The great Vesalius, in support of this idea, speaks of a bundle of willow-twigs bound in a pyramid.[4] It is implied that as the apex is drawn to the base, the sides

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[4] Andreas Vesalius (1514–1564), *De Humani Corporis Fabrica*, Basle, 1543, *Lib. 6, Cap. 10*, p. 587. It is interesting to note how Vesalius described fairly well the gross structures of the heart, and then fitted them as best he could into the Galenical system.

bulge outward, the cavities dilate, the ventricles take the shape of cupping glasses, and suck the blood into them. But all the fibers constrict the heart at the same time that they make it tense, thus thickening the walls and substance rather than enlarging the ventricles. As the fibers stretch from the apex to the base of the heart, drawing the apex toward the base, they do not tend to make the walls bulge outwards, but rather the reverse, for all fibers spirally arranged become straight on contraction. This is true of all muscular fibers. When they contract they shorten longitudinally and distend sidewise as they thicken, as noted in the bellies of muscles generally. To this may be added that the ventricles are not constricted only by virtue of the direction and thickening of their walls. The walls contain solely circular fibers, but there are also bands containing only straight fibers, which are noted in the ventricles of larger animals and which are called nerves by Aristotle.[5] When they contract together an excellent system is present to pull the internal surfaces closely together, as with cords, in order to eject the blood with greater force.

[5] The inside walls of the ventricles are ridged with many projecting bands of muscle tissue, arranged as (1) separate threads stretched across the cavity, the *moderator bands* especially noted in the right ventricle; (2) columns on the walls, the *columnae carneae*, which are probably referred to here, and (3) small elevations on the walls, *papillary muscles*, which are prolonged in the *chordae tendineae* extending to the valves. The latter probably aid in closing more exactly the valve flaps. See R. Burton-Opitz's *Physiology*, Phila. and London, 1920, p. 267–270. Harvey discusses these "bands" again in Chapter XVII.

Likewise, it is not true, as commonly believed, that the heart by its own action or distention draws blood into its ventricles. When it moves and contracts it expels blood, when it relaxes and is quiet it receives blood in the manner soon to be described.

Chapter III

The Movements of the Arteries as Seen in Animal Experimentation

IN CONNECTION with the movements of the heart one may observe these facts regarding the movements and pulses of the arteries:

1. At the instant the heart contracts, in systole, and strikes the breast, the arteries dilate, give a pulsation, and are distended. Also, when the right ventricle contracts and expels its content of blood, the pulmonary artery beats and is dilated along with the other arteries of the body.

2. When the left ventricle stops beating or contracting, the pulsations in the arteries cease, or the contractions being weak, the pulse in the arteries is scarcely perceptible. A similar cessation of the pulse in the pulmonary artery occurs when the right ventricle stops.

3. If any artery be cut or punctured, the blood spurts forcibly from the wound when the left ventricle contracts. Likewise, if the pulmonary artery is cut, blood vigorously squirts out when the right ventricle contracts.

In fishes, also, if the blood vessel leading from the heart to the gills is cut open, the blood will be seen to spurt out when the heart contracts.

Finally, in arteriotomy, the blood is seen squirted alternately far and near, the greater spurt coming with the distention of the artery, at the time the heart strikes the ribs. This is the moment the heart contracts and is in systole, and it is by this motion that the blood is ejected.

Contrary to the usual teaching, it is clear from the facts, that the diastole of the arteries corresponds to the systole of the heart, and that the arteries are filled and distended by the blood forced into them by the contraction of the ventricles. The arteries are distended because they are filled like sacs, not because they expand like bellows. All the arteries of the body pulsate because of the same cause, the contraction of the left ventricle. Likewise the pulmonary artery pulsates because of the contraction of the right ventricle.

To illustrate how the beat in the arteries is due to the impulse of blood from the left ventricle, one may blow into a glove, distending all the fingers at one and the same time, like the pulse. The pulse corresponds to the tension of the heart in frequency, rhythm, volume, and regularity. Because of the motion of the blood it is reasonable to expect the heart beat and the dilatation of the arteries, even the more distant ones, to go together.[1] It is like inflating

[1] Rather interesting that Harvey should have avoided the idea of a transmission of the pulse-wave, especially since in Chapter 5 he discusses the transmission of the wave of contraction over the heart itself. Did he attempt to time with the inadequate instruments of his day the apex beat and say the pulse at the wrist? It is rather a broad conclusion

a glove or bladder, or like in a drum or long beam, when the stroke and beat occur together, even at the extremities. Aristotle says (*De Animal. 3, Cap. 9*), "*The blood of all animals throbs in the veins* (arteries are meant), *and by the pulse is sent everywhere at once.*" And again (*De Respirat. Cap. 15*), "*All veins pulsate together intermittently, because they all depend on the heart. As it is always in intermittent movement, so they move together, intermittently.*" It is to be noted, according to Galen (*De Plac. Hippocr. & Plat., Cap. 9*), that the ancient philosophers referred to the arteries as veins.

I once had a case in charge which convinced me of this truth. This person had a large pulsating tumor, called an aneurysm, on the right neck where the subclavian artery descends toward the axilla. Caused

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to reach, that the pulse corresponds in all particulars to the heart beat, and it is reasonable to believe Harvey studied and pondered over the problem for a long time.

Erasistratus noted that the pulse progresses as a wave, but this was denied by Galen. Both Albrecht von Haller (1708–1777), *Elementa Physiologiae* 1757, tom. 1, p. 447, and M.-F.-Xavier Bichat (1771–1802), agreed with Harvey that the pulse is synchronous in all the arteries. Ernst Heinrich Weber (1795-1878) in 1827 first showed a delay in transmission. From his observations, first printed in his *Pulsum arteriarum*, Leipzig, 1827, one may calculate the velocity of the pulse-wave to be 9.2 meters per second, and its length 3 meters. More recent determinations of the velocity show it to be somewhat slower (see W. H. Howell's splendid Physiology, 10th Ed., Phila., 1927, p. 527). For an authoritative appreciation of E. H. Weber, consult P. M. Dawson's delightful account in the William Snow Miller Festschrift, the May 1928 issue, Vol. 25, of the Quarterly of the Phi Beta Pi Medical Fraternity. The velocity of blood-flow, in a given vessel, an entirely different proposition, was carefully investigated by Carl Ludwig (1816–1895).

by the erosion of the artery itself, it was daily getting larger, and was distended with each pulsation by the rush of blood from the artery. Post mortem examination showed the relation of the parts. The pulse in this same arm was small because the greater part of the blood to it was intercepted by the tumor.

Wherever the motion of the blood in the arteries is impeded, by compression, by infarction, or by interception, there is less pulsation distally,[2] since the beat of the arteries is nothing else than the impulse of blood in these vessels.

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[2] It is remarkable that the clinical applications of Harvey's work were so long neglected. Here and later he clearly indicates how his views may aid in diagnosis, treatment, and prognosis. The practicing physicians, however, would have none of it. Even some manuscript notes of Wm. Cullen's (1712–1790) lectures on the Practice of Physic, over a century later, only refer casually to the use of Dr. Harvey's observations on the control of hemorrhage. It may be that the practical success of Thomas Sydenham (1624–1689) as a physician focused attention on the neat pigeon-holing scheme of his classification of disease by symptoms (nosology), so that the applications of the new work in anatomy and physiology to medicine were overlooked.

Chapter IV

The Motion of the Heart and its Auricles as Noted in Animal Experimentation

IN ADDITION to the motions of the heart already considered, those of the auricles are also to be discussed.

It has been reported by two skilled anatomists, Caspar Bauhin (*lib. 2, cap. 21*) and John Riolan[1] (*lib. 8, cap. 1*), that if the motions of the heart of a living animal are carefully watched, four movements distinct in time and place are to be seen, of which two belong to the auricles and two to the ventricles. In spite of these authorities, there are

[1] Caspar Bauhin (1560–1624) was Professor of Botany and Anatomy in Basle. His *Theatrum Anatomicum* (1605) is an unoriginal but reliable text. John Riolan (1577–1657) was generally regarded as the leading anatomist of his day. As Professor of Anatomy and Pharmacy, and Dean of the Medical Faculty of the University of Paris, he was an extremely influential conservative. On the basis of fairly reasonable arguments, he opposed Harvey's views on the circulation in his *Encheiridium Anatomicum* (1648), and *Opuscula Anatomica Nova* (1649). This was the only criticism against which Harvey deigned to reply, in his *Exercitationes duae anatomicae de circulatione sanguinis ad Jo. Riolanum* (1649). These are available in the beautiful English of Robert Willis' 1847 translations of Harvey's works for the Sydenham Society. For an admirable account of Riolan's views, see J. C. Dalton's scholarly *Doctrines of the Circulation*, Phila., 1884. Riolan's book, to which Harvey probably refers here, is his *Anthropographia* (1618).

not four movements distinct in time, but only in space. The two auricles beat together and so do the two ventricles, so that there are four distinct movements in space, but only two in time. This happens as follows.

Two sets of movements occur together, one of the auricles, another of the ventricles. These are not simultaneous, but that of auricles precedes that of the rest of the heart. The movement seems to start in the auricles and to spread to the ventricles.[2] When the heart slows in approaching death, or in fishes and cold-blooded animals, there is a pause between the two movements, and the heart seems to respond to the motion as if aroused, sometimes quickly, sometimes slowly. At length, nearly dead, it fails to respond to the motion, and it stirs so obscurely that the only signs of motion are pulsations of the auricle, as if just lightly nodding the head. The heart thus stops beating before the auricles, and the latter may be said to outlive it. The left ventricle stops beating first of all, then its auricle, then the right ventricle, and, finally, as indeed Galen noted, when all the rest is quiet and dead, the right auricle still pulsates. Life, therefore, seems to remain longest in the right auricle. While the heart gradually dies, it sometimes responds with a

[2] The first clear statement on the problem of the origin and conduction of the heart beat. For a recent comprehensive discussion of this question see Eyster, J. A. E. and Meek, W. J., Physiological Reviews, 1: 1 (1921).

single weak and feeble beat to two or three pulsations of the auricles.[3]

With the auricles still pulsating after the heart has stopped, it is noteworthy that a finger placed on the ventricles perceives the separate pulsations of the auricles for the same reason as the beat of the ventricles in the arteries is felt, because, as was said before, of the distention from the impact of

[3] The first observation of heart-block. The great Haller (1708–1777) later postulated a peristaltic muscular wave from the vena cava to the aorta over the heart, but Moritz Schiff (1823–1896), by noting again what Harvey had observed in the dying heart, showed this concept untenable. The term "heart-block" was introduced by W. H. Gaskell (1847–1914), in his masterful analysis of the heart beat (Phil. Tr., Lond., 173: 933, 1882) which soundly established the "myogenic" theory of the movement. In this treatise "it is shown that the motor influences from the nerve ganglia in the sinus venosus influence the rhythm (rate and force) of the heart, but do not originate its movements or beat, which are due to the automatic rhythmic contractile power of the heart muscle itself and to the peristaltic contraction wave which proceeds from sinus venosus to bulbus arteriosus and from muscle fiber to muscle fiber" (Garrison). Much of this may be deduced from Harvey's observations in this Chapter. Gaskell's studies were extended by T. W. Engelmann (1843–1909). They gave a new interpretation to the classical experiments of H. Stannius (1808–1883) who showed (Müller's Arch., 1852, 163) that a ligature around the sino-auricular junction would stop the heart, while a second ligature around the auricular-ventricular groove would be followed by slow ventricular beats. W. His, Jr., in 1893, found a thin strip of muscle between the auricles and ventricles, which according to Gaskell's ideas, serves as the conducting medium for the contractile impulses between auricles and ventricles. The clinical significance of heart-block or Stokes-Adams disease was first emphasized by R. Adams (1791–1875) in the Dublin Hospital Reports 4: 396, 1827, and by W. Stokes (1804–1878) in the Dublin Quarterly Journal of Medical Science, 2: 73, 1846. The clinical study of these phenomena has been greatly facilitated by electrocardiographic methods developed chiefly by W. Einthoven (K. Acad. Amster. Proc. Sect. Sc., 6: 107, 1903).

blood. At this same time when the auricles alone are beating, if you cut off the tip of the heart with a scissors, you will see blood gush out at each beat of the auricles. This shows how blood enters the ventricles, not by the suction or dilatation of the ventricles, but by the beat of the auricles.

Note that when I speak of the pulsations of the auricles or of the heart, I mean contractions. First the auricles contract, then afterwards the heart itself. When the auricles contract they become pale, especially when they hold little blood (for they are filled as reservoirs, the blood freely pressing toward them through the veins).[4] This whiteness is most apparent near their edges when they contract.

In fishes, frogs and other animals having a single ventricle in the heart, at the base of which the auricle is swollen like a bladder with blood, you may see this bladder contract first, plainly

[4] The first intimation of the existence of venous pressure. A more literal translation would read "freely tending by the compressing motion of the veins." While the veins are not now considered to exert much elastic pressure, it is taught that muscular activity exerts pressure on the veins. Harvey discusses the functions of the venous valves in Chapter 13. There is little emphasis in current physiological texts on auricular contraction filling the ventricles, although careful investigators estimate that between 18 and 60 per cent of the blood content of the ventricles is forced in by auricular contraction (Wiggers, C. J., *The Circulation in Health and Disease*, Phila., 2nd Ed., 1923.) The current opinion is that venous pressure largely determines the diastolic filling, and thus the "stroke-volume" of the ventricles. For a recent review of the significance of venous pressure, consult J. A. E. Eyster's paper, Physiological Reviews, 6: 281 (Apr.) 1926.

followed afterwards by the contraction of the rest of the heart.

It is only fair to report what I have observed to the contrary. The heart of an eel, of certain fishes, and even of other animals, may beat without the auricles. Even if it is cut in pieces, the separate parts may be seen to contract and relax.[5] So even after auricular movement has stopped, the body of the heart may beat and pulsate. But may not this be characteristic of those animals more tenacious of life, whose basic humor is more glutinous or sluggish, and not easily dissipated? The same thing is noted in the flesh of eels, which continues to wriggle even after skinning and slicing in pieces.

In an experiment one time on a pigeon, after the heart had stopped, and even after the auricles were motionless for some time, I placed my finger, warm and kept wet with saliva, upon the heart. By this warm application it recovered life and strength, the auricles and ventricles beat, alternately contracting and relaxing, apparently recalled from death.[6]

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[5] An astonishingly brief significant observation from which may be deduced the three fundamental and characteristic properties of cardiac muscle: automaticity, contractility, and rhythmicity.

[6] The first recorded "perfusion" of an isolated heart, again demonstrating the basic properties of cardiac muscle. Only an Englishman could append at that time the last phrase of this paragraph without thought of its theological consequences. Galileo was forced to renounce his scientific ideas before a Papal tribunal in 1632, and in Germany the horrible Thirty Years War was in full swing.

Besides this I have sometimes noticed, after the heart and even the right auricle had completely stopped beating, that a slight motion or palpitation remained in the blood in the right auricle, as long as it seemed imbued with heat and spirit.

Something similar is very apparent in embryology, as may be seen during the first seven days of the hatching of a hen's egg. First, before anything else, a drop of blood appears, which throbs, as Aristotle had noted. From this, with increasing growth and formation of the chick, the auricles of the heart are made, in the pulsations of which there is continual evidence of life. After a few more days, when the body is outlined, the rest of the heart is made, but for some time it remains pale and bloodless like the rest of the body, and does not throb. I have seen a similar condition in a human embryo about the beginning of the third month, the ventricles being pale and bloodless, but the auricles containing some purple blood. In the egg, when the fetus forms and develops, the heart grows also and acquires ventricles, with which blood is received and transmitted.

Whoever examines this matter closely will not say that the heart entirely is the first to live and the last to die, but rather the auricles (or that part corresponding to the auricles in serpents, fishes, and such animals) which live before the rest of the heart, and die after it.

I should say rather that the blood itself or spirit has in it an obscure throbbing which it seems to hold

after death, and whether we may say that life begins with a cardiac palpitation is doubtful.[7] The seminal fluids or prolific spirit, of all animals, as Aristotle noted, goes forth with a bound, as if alive. Nature in death turns back, retracing her steps, as Aristotle says (*De Motu Animal., Cap. 8*), and comes again to the place from which she started. In the generation of life, what is not animal develops to animal, a non-entity to an entity, and by retrogression in corruption returns from an entity to a non-entity. So in animals what is made last dies first, what first dies last.

I have observed that there is a heart in almost all animals, not only in the larger ones with blood, as Aristotle claims, but in the smaller bloodless ones also, as snails, slugs, crabs, shrimps, and many others. Even in wasps, hornets, and flies, have I seen with a lens a beating heart at the upper part of

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[7] One must admire the intellectual courage of Harvey in this sort of speculation. Aristotelian in the philosophical aspects of his work, Harvey is not here specifically attempting to locate the anatomical seat of the soul, although that is implied. His demonstration really stopped this vain search (H. M. Brown, Annals of Medical History, 5: 1, 1923).

Note through here not only the remarkable embryological observations (later developed in his *Exercitationes de generatione animalium*, 1651), but also the extraordinary remarks on invertebrate anatomy and physiology. These are the first of any significance since Aristotle, of whom surely Harvey was the first real disciple. Both P. Belon (1517–1564) and G. Rondelet (1509–1566)—Rabelais' "Rondibilis," wrote valuable texts on fishes, 1551 and 1554, but they did not discuss lower forms. In the last paragraph of this Chapter, one may sense the wonder and awe Harvey must have felt as he pondered on what he saw.

what is called a tail, and I have shown it living to others.

In these bloodless animals the heart beats slowly, contracting sluggishly as in moribund higher animals. This is easily seen in the snail, where the heart lies at the bottom of that opening on the right side which seems to open and close as saliva is expelled. The incision should be made on the top of the body near the part corresponding to the liver.

It is to be noted that in winter and cold seasons, the bloodless animals, as the snail, show no pulsation. They seem to live like vegetables or those things called plant-animals.

It is also to be noted that an auricle or its analogue is present in all animals possessing a heart, and where there is a double ventricle, there are always two auricles, but not the reverse. But turning to the development of the chick in the egg, there is, as I said, only a vesicle or auricle, at first, or a throbbing drop of blood, which, as growth progresses, becomes the heart. So in some animals, not reaching the highest organization, as bees, wasps, snails, shrimps, and craw-fish, there is a throbbing vesicle or an alternately red and white point, as the mainstay of life.

There is a small squid, called a *shrimp* in English, *een gerneel* in Flemish, which is caught at sea and in the Thames, whose entire body is transparent. Placing this creature in water, I have often shown some of my friends the movements of its heart with

great clearness. Since the outside of the body did not block our view, we could observe the least tremor of the heart, as through a window.

I have seen the first rudiments of the chick as a little cloud in the hen's egg about the fourth or fifth day of incubation, with the shell removed and the egg placed in clear warm water. In the center of the cloud there was a throbbing point of blood, so trifling that it disappeared on contraction and was lost to sight, while on relaxation it appeared again like a red pin-point. Throbbing between existence and non-existence, now visible, now invisible, it was the beginning of life.

Chapter V

The Actions and Functions of the Heart

FROM these and other observations I am convinced that the motion of the heart is as follows:

First, the auricle contracts, and this forces the abundant blood it contains as the cistern and reservoir of the veins, into the ventricle. This being filled, the heart raises itself, makes its fibers tense, contracts, and beats. By this beat it at once ejects into the arteries the blood received from the auricle; the right ventricle sending its blood to the lungs through the vessel called the *vena arteriosa*, but which in structure and function is an artery; the left ventricle sending its blood to the aorta, and to the rest of the body through the arteries.

These two motions, one of the auricles, the other of the ventricles, are consecutive, with a rhythm between them,[1] so that only one movement may

[1] The auricular-ventricular rhythm has become an important subject for investigation and discussion since the introduction of electrocardiographic studies by means of W. Einthoven's (1860–1927) string galvanometer. See F. H. Garrison's *History of Medicine*, 3rd Ed., Phila., 1921, p. 735.

Note the excellent description of the chain of events in the act of swallowing. Here is an example of that straight-forward mechanistic description of functional activity in which Harvey so closely approxi-

be apparent, especially in warm-blooded animals where it happens rapidly. This is like a piece of machinery in which one wheel moves another, though all seem to move simultaneously, or like the mechanism in fire-arms, where touching the trigger brings down the flint, lights a spark, which falls in the powder and explodes it, firing the ball, which reaches the mark. All these events because of their quickness seem to occur simultaneously in the twinking of an eye. Likewise in swallowing: lifting the tongue and pressing the mouth forces the food to the throat, the larynx and the epiglottis are closed by their own muscles, the gullet rises and opens its mouth like a sac, and receiving the bolus forces it down by its transverse and longitudinal muscles. All these diverse movements, carried out by different organs, are done so smoothly and regularly that they seem to be a single movement and action, which we call swallowing.

So it happens in the movement and action of the heart, which is sort of a deglutition or transference of blood from the veins to the arteries. If anyone with these points in mind will carefully watch the cardiac action in a living animal, he will see, not only what I have said, that the heart contracts in a continuous movement with the auricles, but also a

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mates the current attitude. The classical descriptions of deglutition are by F. Magendie (1783–1855), Précis élément. de Physiol., 2: 58, 1817, and by H. Kronecker (1839–1914) and S. J. Meltzer (1851–1921), Arch. f. Physiol., 1880, 299 and 446.

peculiar side-wise turning toward the right ventricle as if it twists slightly on itself in performing its work. It is easy to see when a horse drinks that water is drawn in and passed to the stomach with each gulp, the movement making a sound, and the pulsation may be heard and felt. So it is with each movement of the heart when a portion of the blood is transferred from the veins to the arteries, that a pulse is made which may be heard in the chest.[2]

The motion of the heart, then, is of this general type. The chief function of the heart is the transmission and pumping of the blood through the arteries to the extremities of the body. Thus the pulse which we feel in the arteries is nothing else than the impact of blood from the heart.

Whether or not the heart, besides transferring, distributing and giving motion to the blood, adds anything else to it, as heat, spirits, or perfection, may be discussed later and determined on other grounds. It is enough now to have shown that during the heart beat the blood is transferred through the ventricles from the veins to the arteries, and distributed to the whole body.

This much may be generally admitted on the basis of the structure of the heart and the position and

[2] One of the first observations of heart-sounds. An interpretation of their significance together with clinical application was made by R.-T.-H. Laënnec (1781–1826) in his epochal *Traité de l'auscultation médiate* (1819). See W. H. Howell's Physiology, 10th Ed., Phila., 1927, p. 557. For a history of knowledge of heart sounds, Garrison refers to G. Joseph, Janus, 2: 1, 345, 565, 1853.

action of its valves. But contradictory and incoherent statements are made about the matter by some who stumble around in the dark, saying much on conjecture only, as has been pointed out before.

The chief cause of perplexity and error in this matter seems to me to be the close connection between the heart and lungs in man. When the so-called venous artery, and arterial vein, were both seen to disappear into the lungs, it was very puzzling to determine how the right ventricle might distribute blood to the body or the left draw blood from the vena cava. This was implied by Galen in controverting Erasistratus on the origin and function of the veins, and the formation of blood (*De Placit. Hippocrat. & Plat., cap. 6*), "*You will reply that this is true, that the blood is made in the liver, and then carried to the heart to receive its correct form and full perfection. This is not unreasonable, no great or perfect work is finished at one effort, nor can it get its whole polish from one tool. But if this is really so, show us another vessel which takes the perfect blood from the heart, and distributes it, as the arteries do the spirits, to the whole body.*" Thus Galen would not consent to a reasonable opinion, because not seeing a way of transit, he could not discover a vessel to spread the blood from the heart to the whole body!

I wonder what that great and ingenious man would have replied, had someone appeared for Erasistratus, or for that opinion now held by us and admitted to be reasonable by Galen himself, and had then pointed

to the aorta as the vessel for distributing blood from the heart to the rest of the body? Had he said this transmits spirits and not blood, he would have sufficiently answered Erasistratus, who thought the arteries contained spirits alone. But he would have thus contradicted himself, and basely denied what he had strongly argued in his writings against this same Erasistratus, in showing by many potent reasons and by experiment that the arteries contain blood and not spirits.

The great man often agrees in this connection that "*all arteries arise from the aorta, and this from the heart, all normally containing and carrying blood.*" He says further, "*The three semilunar valves, placed at the opening of the aorta, prevent the reflux of blood into the heart. Nature would never have connected them with such an important organ unless for some great purpose.*" If the "Prince of Physicians" admits all this, as quoted in his very words from the book cited, I do not see how he can deny that the aorta is the very vessel to carry the blood, properly perfected, from the heart to the whole body. Does he hesitate, as all after him to the present, because he could not see on account of the close connection between heart and lungs, a way by which blood might go from veins to arteries?

This matter greatly bothered the anatomists. Always finding in dissection the pulmonary vein[3]

[3] This is one of the few places where a slip was made by Robert Willis, the great Sydenham Society translator of Harvey (1847). He

and the left ventricle filled with thick clotted blood, they were forced to say that blood oozed through the septum of the heart from the right ventricle to the left. I have already refuted this notion. A new path is to be found and described. This done, I believe there will be no more difficulty in agreeing with what I suggest about the beat of the heart and arteries, the transfer of blood from veins to arteries and its distribution to the body through the arteries.

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calls the vessel the "pulmonary artery," and every editor of the translation has passed it by, when the context alone should raise a doubt. The text reads *arteriam venosam*, the artery like unto a vein, or the pulmonary vein.

Chapter VI

The Way by which the Blood Passes from the Vena Cava to the Arteries, or from the Right Ventricle of the Heart to the Left

SINCE the close contact of the heart and lungs in man has probably been a source of error, as I have said, the common practice of anatomists, in dogmatizing on the general make-up of the animal body, from the dissections of dead human subjects alone, is objectionable. It is like devising a general system of politics, from the study of a single state, or deigning to know all agriculture from an examination of a single field. It is fallacious to attempt to draw general conclusions from one particular proposition.

If only anatomists were as familiar with the dissection of lower animals as with that of the human body, all these perplexing difficulties would, in my opinion, be cleared up.

The situation is first of all clear enough in fishes, where there is a single ventricle in the heart, and no lungs. The sac at the base of the heart, doubtless corresponding to the auricle, pushes the blood into

the heart, which plainly transmits it by a tube analogous to an artery. This may be confirmed by inspection, or section of the artery, the blood spurting with each beat of the heart.

It is not hard to see the same thing in other animals with but a single ventricle, as toads, frogs, serpents and lizzards. They have lungs of a sort, as a voice. I have made notes on the excellent structure of their lungs, but they are not appropriate here. It is obvious in opening these animals that the blood is transferred from the veins to the arteries by the heart beat. The way is wide open; there is no difficulty or hesitancy about it; it is the same as it would be in man were the septum of the heart perforated or removed, making one ventricle of the two. Were this so, no one would doubt, I think, how blood passes from veins to arteries.

Since there really are more animals without lungs than with them, and also more with a single ventricle in the heart than with two, it may be concluded that for the majority of animals, an open way exists for blood to pass through the cavity of the heart from the veins to the arteries.

I have perceived further that the same thing is very apparent in the embryos of animals possessing lungs.

It is well known by all anatomists that the four blood vessels belonging to the heart, the vena cava, pulmonary artery, pulmonary vein, and aorta, are connected differently in the fetus than in the adult.

In the fetus a lateral anastomosis joins the vena cava to the pulmonary vein. This is located before the vena cava opens into the right ventricle of the heart, or gives off the coronary vein, just above its exit from the liver. This is a good-sized oval-shaped hole opening a passage from the vena cava to the pulmonary vein, so that blood may freely flow from the one to the other, then into the left auricle of the heart, and then to the left ventricle. In this *foramen ovale*, there is a thin tough membrane, larger than the opening, hanging like a cover from the pulmonary vein side. In the adult this blocks the foramen, and adhering on all sides, finally closes and obliterates it. In the fetus, however, this membrane hangs loosely, opening an easy way to the lungs and heart for the blood flowing from the vena cava, but at the same time blocking any passage back into that vein. In the embryo, one may conclude then that blood continually passes through this foramen from the vena cava to the pulmonary vein, and then into the left ventricle of the heart. After making this passage, it can not regurgitate.

Another junction is by the pulmonary artery where it divides into two branches after leaving the right ventricle. It is like a third trunk added to these two, a sort of arterial canal passing obliquely toward and perforating the aorta. Thus in dissecting a human embryo it appears as though there were two aortae or roots of the great artery rising from the heart.

This canal gradually shrinks after birth and is finally obliterated like the umbilical vessels.

There is no membrane in this arterial canal to impede the movement of the blood in either direction. At the entrance of the pulmonary artery, from which this canal extends, there are three sigmoid valves opening outwards, so the blood flows easily from the right ventricle into this vessel and the aorta, but by closing tightly they prevent any back flow from the arteries or lungs into the right ventricle. Thus when the heart contracts in the embryo, there is reason to believe the blood is continually propelled through this way from the right ventricle to the aorta.

It is commonly said that these two great junctions are for the nourishing of the lungs. This is improbable and inconsistent, since they are closed up and obliterated in the adult, although the lungs then, because of their heat and motion, must be thought to require more nourishment. It is also false to claim that Nature had to make these passages to nourish the lungs because the heart does not beat nor move in the embryo. Nature feels no such need, for in the hatching egg, and in the human embryo, removed quickly from the uterus at an autopsy, the heart beats just as in an adult. I am not alone in often seeing these movements, for Aristotle testifies (*Lib. de Spir., cap. 3*), "*Being part of the constitution of the heart, the pulse appears at its very beginning, as may be seen in animal experiments, and in the formation of the chick.*" These passages are not only open to the time of

birth in man, and in certain animals, but even for many months in others, as anatomists have noted, and for years or life in still others, as in the goose, snipe, and many birds and small animals. This perhaps persuaded Botallus[1] that he had found a new passage for blood from the vena cava to the left ventricle. I confess I almost thought so myself when I first saw the condition in larger adult mice.

From this it appears that the same thing happens in human and other embryos in which these junctions are not closed: the heart, in its beat, forces the blood through the wide open passages from the vena cava to the aorta through the two ventricles. The right ventricle, receiving blood from its auricle, propels it through the pulmonary artery and its continuation, called the *ductus arteriosus*, to the aorta. At the same time the left ventricle contracts and sends into the aorta the blood, which, received from the beat of its auricle, has come through the foramen ovale from the vena cava.

In embryos, then, while the lungs are as inert and motionless as though not present, Nature uses for transmitting blood the two ventricles of the heart as if they were one. The situation is the same in embryos

[1] L. Bottallus, a French anatomist of little ability, was born about 1530. "His very imperfect description of the *ductus arteriosus*, which we know now to be due to the persistence of the fifth cephalic aortic arch on the left side, appeared in 1565. To call the structure *ductus Botalli* is an anachronism, as it was in fact well known to Galen." (C. Singer, *The Evolutuon of Anatomy*, New York 1925.) With what skill and precision Harvey describes the fetal circulation!

of animals with lungs, while the lungs are not used, as in those animals themselves without lungs.

So it seems obviously true in the fetus that the heart by its beat transfers blood from the vena cava to the aorta by as open a passage as if in the adult, as I have said, the two ventricles were united by removing the septum. Since these ways for the passage of blood are so conspicuous in the majority of animals,—indeed in all at certain times,—we must examine another matter. Why may we not conclude that this passage is made through the substance of the lungs in warm-blooded adult animals as man? Nature made these ways in the embryo at a time when the lungs were not used, apparently because of the lack of a passage through them. Why is it better, for Nature always does what is best, to close completely to the passage of blood in adolescence those open ways which are used in the embryos of so many animals, without opening any others for this transfer of blood?

The situation is such that those who seek the ways in man by which blood reaches the pulmonary vein and left ventricle from the vena cava, will do best to proceed by animal experimentation.[2] Here the reason

[2] Most of Harvey's doctrine was developed from studies in comparative anatomy and physiology. He was acutely aware of the value of animal experimentation, which had already been specifically recommended by Vesalius (1514–1564) and Realdus Columbus (1516–1559). There is evidence that Harvey deplored the suffering involved in animal experimentation, and that he spoke feelingly on it. (S. Weir Mitchell, *Some Recently Discovered Letters of William Harvey*, Phila.,

may be found why Nature, in larger adult animals, filters the blood through the lungs instead of choosing a direct path. No other way seems possible. It may be the larger, more perfect animals are warmer and when full grown their greater heat is thus more easily damped. For this reason the blood may go through the lungs, to be cooled by the inspired air and saved from boiling and extinction.[3] There may be other reasons. To discuss and argue these points would be to speculate on the function of the lungs. I have made many observations on this matter, on ventilation, and on the necessity and use of air, as well as on the various organs in animals concerned in these matters. Nevertheless I shall leave these things to be more conveniently discussed in a separate tract lest I seem to wander too far from the proposition of the motion and function of the heart, and to confuse the question. Returning to our present concern, I shall go on with my demonstration.

1912, p. 50.) He may have used opium preparations to give analgesia but there is no evidence favoring this view. It is not likely that he performed many experiments on higher animals, except such as were caught wounded in the King's hunts. R. Hannah has painted such a scene, where Harvey is demonstrating to Charles the heart of a deer slain in the chase.

[3] The innate heat was supposed to reside in the blood, and the older theories on the heart beat and movement of the blood included the idea that the blood boiled up in the heart, and "boiled over" into the vessels, thus causing the heart beat and pulse. The function of respiration was thus to cool the heart. It is peculiar that Harvey should have permitted himself to utter this speculation when he so sarcastically attacked the current ideas on respiration and the cooling of the blood in the introduction.

In the more perfect warm-blooded adult animals, as man, the blood passes from the right ventricle of the heart through the pulmonary artery to the lungs, from there through the pulmonary vein into the left auricle, and then into the left ventricle. First I shall show how this may be so, and then that it is so.

Chapter VII

The Passage of Blood Through the Substance of the Lungs from the Right Ventricle of the Heart to the Pulmonary Vein and Left Ventricle

THAT this may be so, and that there is nothing to keep it from being so, is evident when we consider how water filtering through the earth forms springs and rivers, or when we speculate on how sweat goes through the skin, or urine through the kidneys. It is well known that those who use Spa waters, or those of *La Madonna* near Padua, or other acid waters which are drunk by the gallon, pass them all off in an hour or so by the bladder. So much fluid must tarry a while in the digestive tract, it must pass through the liver (everyone agrees that the alimentary succus goes through this organ at least twice daily),[1] through the veins, the substance of the kidneys, and through the ureters into the bladder.

I know there are those who deny that the whole mass of blood may pass through the lungs as the alimentary juices filter through the liver, saying it is

[1] I can't trace the origin of this quaint notion. Perhaps it refers to the two chief meals of the day.

impossible and unbelievable. They are of that class of men, as I reply with the poet, who promptly agree or disagree, according to their whim, fearful when wanted, bold when there is no need.

The substance of the liver and also of the kidney is very dense, but that of the lung is much looser, and in comparison with the liver and kidney is spongy.[2]

There is no propulsive force in the liver, but in the lung the blood is pushed along by the beat of the right ventricle of the heart, which must distend the vessels and pores of the lung. Again, as Galen indicates (*De Usu Part., cap. 10*), the continual rising and falling of the lungs in respiration must open and close the vessels and porosities, as in a sponge or thing of similar structure when it is compressed and allowed to expand.[3] The liver, however, is quiet, it never seems to expand or contract.

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[2] This later developed into the question of an "open" or a "closed" circulation through an organ. The microscopic structure of the internal organs, which gives the clue to their architecture and functional mechanism, was first investigated by Marcello Malpighi (1628–1694), the brilliant Italian scientist. In his *De pulmonibus* (1661) he gave the first clear conception of the structure of the lung, and completed Harvey's demonstration (announced the year of his birth) by proving the capillary anastomoses between arteries and veins. In his *De Viscerum structura* (1666) he outlined the structure of the liver, spleen, and kidney. The best modern work on the architecture of the kidney has been done by J. Henle (1809–1885), of the liver by F. P. Mall (1862–1917), and of the lung by W. S. Miller (1858———). The question of an open versus a closed circulation through an organ seems to be settled in favor of the latter.

[3] Respiration does considerably influence blood-pressure. It is generally agreed that blood-pressure rises during inspiration and falls during expiration. For a discussion of the factors involved, see: R.

No one denies that all the ingested nourishment may pass through the liver to the vena cava in man and all large animals. If nutrition is to proceed, nutriment must reach the veins, and there appears to be no other way. Why not hold the same reasoning for the passage of blood through the lungs of adults, and believe it to be true, with Columbus, that great anatomist, from the size and structure of the pulmonary vessels, and because the pulmonary vein and corresponding ventricle are always filled with blood, which must come from the veins and by no other route except through the lungs? He and I consider it evident from dissections and other reasons given previously.

Those who will agree to nothing unless supported by authority, may learn that this truth may be confirmed by the words of Galen himself, that not only may blood be transmitted from the pulmonary artery to the pulmonary vein, then into the left ventricle, and from there to the arteries, but that this is accomplished by the continual beat of the heart and the motion of the lungs in breathing.

There are three sigmoid or semilunar valves at the opening of the pulmonary artery, which prevent blood forced into this pulmonary artery from flowing back into the heart. Galen clearly explains the functions of these valves in these words (*De Usu Part., Lib. 6, cap. 10*): "*There is generally a mutual anastomo-*

Burton-Opitz' Physiology, Phila., 1920, p. 390–393, and W. H. Howell's Physiology, Phila., 1927, 10th Ed., p. 670–673.

sis or joining of the arteries and veins, and they transfer blood and spirit equally from each other by invisible and very small passages. If the mouth of the pulmonary artery always stayed open and Nature had no way of closing it when necessary or of opening it again, the blood could not transfuse through these invisible and delicate pores in the arteries during the contraction of the thorax. All things are not equally attracted or expelled. Something light is more easily drawn in by the distention of the part, and pushed out in contraction than something heavy. Likewise anything is more quickly passed through a wide tube than through a narrow one. When the thorax contracts, the pulmonary veins, strongly compressed on all sides, quickly expel some of the spirits in them, and take some blood from these tiny mouths. This could never happen if blood could flow back into the heart through the large opening of the pulmonary artery. Thus, its return through this great hole being blocked, and being compressed on every side, some of it filters into the arteries through these small pores."

Shortly after, in the next chapter: "*The more powerfully the thorax contracts, squeezing the blood, the more tightly do these membranes, the sigmoid valves, close the opening, so that nothing flows back.*" A little before in the 10th chapter: "*Unless the valves be present, much difficulty would follow. The blood would follow this long course in vain, flowing in during the distention of the lungs and filling all the vessels in it, outwards during the constrictions, and tide-like, as Euripus, flow back and forth in a way not suited to the*

blood. This may not seem of much importance. Respiratory function, however, would suffer, and this would be of no little significance." Again, a little later: "*Another serious inconvenience would follow if our Maker had not provided these valves, the blood would move backwards during expirations.*" So, in the 11th chapter, he concludes: "*It seems that all these valves have a common function in preventing regurgitation, appropriate to both directions, one set leading away from the heart and preventing return by that route, the other leading into the heart and preventing escape from it. Nature never wished to fatigue the heart with useless work, neither bringing anything unnecessarily to it, nor taking anything unnecessarily from it. Thus there are four openings, two in each ventricle, one of which leads into the heart, the other out of it.*" A bit farther on: "*One of the blood-vessels fastened on the heart has a simple tunic, the other leading from it has a double tunic.* (Galen is referring to the right ventricle, but the same things apply to the left.) *The same cavity being provided for both of these, blood enters through the former and leaves through the latter.*"

Galen proposes this argument to explain the passage of blood from the vena cava through the right ventricle to the lungs. By merely changing the terms, we may apply it more properly to the transfer of blood from the veins through the heart to the arteries. From the words of that great Prince of Physicians, Galen, it seems clear that blood filters through the lung from the pulmonary artery to the

pulmonary vein as a result of the heart beat and the movement of the lungs and thorax. (Consult Hofmann's excellent Commentary on Galen's 6th Book, *De Usu Part.*, which I saw after writing this.)[4] The heart, further, continually receives blood in its ventricles, as into a cistern, and expels it. For this reason, it has four kinds of valves, two regulating inflow, and two outflow, so blood will not be inconveniently shifted back and forth like Euripus, neither flowing back into the part from which it should come, nor quitting that to which it should pass, lest the heart be wearied by vain labor and respiration be impeded. Finally, our assertion is clearly apparent, that the blood continually flows from the right to the left ventricle, from the vena cava to the aorta, through the porosities of the lung.

Since blood is constantly sent from the right ventricle into the lungs through the pulmonary

[4] Caspar Hofmann (1572–1648) was Professor of Medicine at Altdorf, and well recognized as one of the leading authorities on Galen. The book to which Harvey refers, *Comment. in Galen. de usu part.*, was published at Frankfort in 1625 (H. Haeser, *Geschichte der Medicin*, Jena, 1881, Vol. 2, p. 264). In 1636, Lord Arundel took his friend Harvey with him on a diplomatic mission to Vienna regarding a peace during the Thirty Years' War. Harvey wrote to Hofmann, offering in a very manly way to demonstrate his doctrines, which he had heard Hofmann opposed. See R. Willis' translation for the Sydenham Society, 1847, p. 595. "Tradition says that Harvey actually gave this demonstration in public, and that it proved satisfactory to everyone except Hofmann himself. The old man—then past the grand climacteric—remained unconvinced, and as he continued to urge objections, Harvey at length threw down his knife and walked out of the theatre" (D'Arcy Power's *William Harvey*. Lond., 1897, p. 114).

artery, and likewise constantly is drawn into the left ventricle from the lungs, as is obvious from what has been said and the position of the valves, it cannot do otherwise than flow through continuously. Then, as blood constantly pours into the right ventricle of the heart, and constantly moves out of the left, it is impossible, for the same reasons as above, obviously reasonable, for it to do otherwise than pass continually from the vena cava to the aorta.

It is evident from dissection that this occurs through wide open channels in all animals before birth, and from Galen's words and what has been said previously it is equally manifest that it occurs in adults by tiny pores and vascular openings through the lungs.[5] So it appears that, whereas one ventricle of the heart, the left, suffices for distributing blood to the body, and drawing it from the vena cava, as

[5] It is interesting to note how much Harvey relies on the traditional authorities to prove his points. The only contemporary authority referred to is R. Columbus (1516–1559), although M. Servetus (1509–1553), and A. Caesalpinus (1524–1603) had also described the pulmonary circulation. The latter, indeed, had discussed the general circulation, so naming the phenomenon, and had postulated *vasa in capillamenta resoluta*, or anastomoses between arteries and veins. Dr. J. C. Hemmeter (Johns Hopkins Hosp. Bull., 16: 165, 1905) suggests, in his excellent essay, that since both Servetus and Caesalpinus had offended the theologians, Harvey was afraid to mention them. It has been observed (Chap. IV, Note 6) that Harvey apparently had little fear of theological consequences. In view of Harvey's honesty it is hard to believe that he really knew of the work of these men. The "vascular openings" between arteries and veins were first demonstrated in the frog's lung by Marcello Malpighi (1628–1694), first great histologist.

is the case in all animals lacking lungs, Nature was compelled, when she wished to filter blood through the lungs, to add the right ventricle, whose beat should force blood from the vena cava through the lungs into the left ventricle. Thus the right ventricle may be said to be made for the sake of transmitting blood through the lungs, not for nourishing them. It is entirely unreasonable to assume that the lungs need so much more abundant nutriment, and coming directly from the heart, so much purer and more spiritous blood than either the very refined substance of the brain, or the very brilliant and perfect structure of the eyes, or the flesh of the heart itself which is adequately nourished by the coronary artery.

Chapter VIII

Amount of Blood Passing Through the Heart from the Veins to the Arteries, and the Circular Motion of the Blood

SO FAR we have considered the transfer of blood from the veins to the arteries, and the ways by which it is transmitted and distributed by the heart beat. There may be some who will agree with me on these points because of the authority of Galen or Columbus or the reasons of others. What remains to be said on the quantity and source of this transferred blood, is, even if carefully reflected upon, so strange and undreamed of, that not only do I fear danger to myself from the malice of a few, but I dread lest I have all men as enemies, so much does habit or doctrine once absorbed, driving deeply its roots, become second nature, and so much does reverence for antiquity influence all men. But now the die is cast; my hope is in the love of truth and in the integrity of intelligence.

First I seriously considered in many investigations how much blood might be lost from cutting the arteries in animal experiments. Then I reflected on the symmetry and size of the vessels entering and leaving the ventricles of the heart, for

Nature, making nothing in vain, would not have given these vessels such relative greatness uselessly. Then I thought of the arrangement and structure of the valves and the rest of the heart. On these and other such matters I pondered often and deeply. For a long time I turned over in my mind such questions as, how much blood is transmitted, and how short a time does its passage take. Not deeming it possible for the digested food mass to furnish such an abundance of blood, without totally draining the veins or rupturing the arteries, unless it somehow got back to the veins from the arteries and returned to the right ventricle of the heart, I began to think there was a sort of motion as in a circle.

This I afterwards found true, that blood is pushed by the beat of the left ventricle and distributed through the arteries to the whole body, and back through the veins to the vena cava, and then returned to the right auricle, just as it is sent to the lungs through the pulmonary artery from the right ventricle and returned from the lungs through the pulmonary vein to the left ventricle, as previously described.

This motion may be called circular in the way that Aristotle says air and rain follow the circular motion of the stars.[1] The moist earth warmed by

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[1] In spite of his own extraordinary discoveries, Harvey was remarkably conservative. N. Copernicus (1473–1543), J. Kepler (1571–1630), and G. Galilei (1564–1642) had overthrown the Ptolemical theory of the circular motion of the stars in the heavenly spheres, but Harvey seems never to have heard of their studies.

the sun gives off vapors, which, rising, are condensed to fall again moistening the earth. By this means things grow. So also tempests and meteors originate by a circular approach and recession of the sun.

Thus it happens in the body by the movement of the blood, all parts are fed and warmed by the more perfect, more spiritous, hotter, and, I might say, more nutritive blood. But in these parts this blood is cooled, thickened, and loses its power, so that it returns to its source, the heart, the inner temple of the body, to recover its virtue.

Here it regains its natural heat and fluidity, its power and vitality, and filled with spirits, is distributed again. All this depends on the motion and beat of the heart.

So the heart is the center of life, the sun of the Microcosm, as the sun itself might be called the heart of the world. The blood is moved, invigorated, and kept from decaying by the power and pulse of the heart. It is that intimate shrine whose function is the nourishing and warming of the whole body, the basis and source of all life. But of these matters we may speculate more appropriately in considering the final causes of this motion.

The vessels for the conduction of blood are of two sorts, the vena cava type and the aortic type. These are to be classified, not on the basis of structure or make-up, as commonly thought with Aristotle, for in many animals, as I have said, the veins do not differ from the arteries in thickness of tunics,

but on the basis of difference in function or use. Both veins and arteries were called veins by the ancients, and not unjustly, as Galen notes. The arteries are the vessels carrying blood from the heart to the body, the veins returning blood from the body to the heart, the one the way from the heart, the other toward the heart,[2] the latter carrying imperfect blood unfit for nourishment, the former perfected, nutritious blood.

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[2] In so clearly differentiating the functions of arteries and veins, why didn't Harvey go on and point out the confusion resulting from the terminology in use at the time with regard to the pulmonary vessels?

Chapter IX

The Circulation of the Blood is Proved by a Prime Consideration

IF ANYONE says these are empty words, broad assertions without basis, or innovations without just cause, there are three points coming for proof, from which I believe the truth will necessarily follow, and be clearly evident.

First, blood is constantly being transmitted from the vena cava to the arteries by the heart beat in such amounts that it cannot be furnished by the food consumed, and in such a way that the total quantity must pass through the heart in a short tme.

Second, blood is forced by the pulse in the arteries continually and steadily to every part of the body in a much greater amount than is needed for nutrition or than the whole mass of food could supply.

And likewise third, the veins continually return this blood from every part of the body to the heart.

These proved, I think it will be clear that the blood circulates, passing away from the heart to the extremities and then returning back to the heart, thus moving in a circle.

Let us consider, arbitrarily or by experiment, that the left ventricle of the heart when filled in

diastole, contains two or three ounces, or only an ounce and a half. In a cadaver I have found it holding more than three ounces. Likewise let us consider how much less the ventricle contains when the heart contracts or how much blood it forces into the aorta with each contraction, for, during systole, everyone will admit something is always forced out, as shown in Chapter III, and apparent from the structure of the valves. As a reasonable conjecture suppose a fourth, fifth, sixth, or even an eighth part is passed into the arteries. Then we may suppose in man that a single heart beat would force out either a half ounce, three drams, or even one dram of blood, which because of the valvular block could not flow back that way into the heart.

The heart makes more than a thousand beats in a half hour, in some two, three, or even four thousand. Multiplying by the drams, there will be in half an hour either 3,000 drams, 2,000 drams, five hundred ounces, or some other such proportionate amount of blood forced into the arteries by the heart, but always a greater quantity than is present in the whole body. Likewise in a sheep or dog, suppose one scruple goes out with each stroke of the heart, then in half an hour 1,000 scruples or about three and a half pounds of blood[1] would be

[1] The Apothecaries or Troy weight is used: 3 scruples equal 1 dram; 8 drams equal 1 ounce; 12 ounces equal 1 pound. This was in

pumped out. But as I have determined in the sheep, the whole body does not contain more than four pounds of blood.

On this assumption of the passage of blood, made as a basis for argument, and from the estimation of the pulse rate, it is apparent that the entire quantity of blood passes from the veins to the arteries through the heart, and likewise through the lungs.

But suppose this would not occur in half an hour, but rather in an hour, or even in a day, it is still clear that more blood continually flows through the heart than can be supplied by the digested food or be held in the veins at any one time.

It cannot be said that the heart in contracting sometimes pumps and sometimes doesn't, or that it propels a mere nothing or something imaginary. This point has been settled previously, and besides, it is contrary to common sense. If the ventricles must be filled with blood in cardiac dilatation, something must always be pushed out in contraction, and not a little amount either, since the passages are not small nor the contractions few. This quantity expelled is some proportion of the contents of the ventricle, a third, a sixth, or an eighth, and an equivalent amount of blood must fill it up in diastole,

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general use in Europe. This chapter is the crucial point in Harvey's argument, and the first instance of the quantitive method in physiology. It introduced the most important method of reasoning in the science and demonstrated its most significant truth.

so that there is a relation between the ventricular capacity in contraction and in dilatation. Since the ventricles in dilating do not become filled with nothing, or with something imaginary, so in contracting they never expel nothing or something imaginary, but always blood in an amount proportionate to the contraction.

So it may be inferred that if the heart in a single beat in man, sheep, or ox, pumps one dram, and there are 1,000 beats in half an hour, the total amount pumped in that time would be ten pounds five ounces; if two drams at a single stroke, then twenty pounds ten ounces; if half an ounce, then forty-one pounds eight ounces; and if one ounce, then a total of eighty-three pounds four ounces, all of which would be transferred from the veins to the arteries in half an hour.

The amount pumped at a single beat, and the factors involved in increasing or diminishing it, may perhaps be more carefully studied later from many observations of mine.[2]

[2] This has remained a most important question ever since. An excellent general review of the subject is Y. Henderson's *Volume Changes of the Heart*, Physiol. Rev., 3: 165, 1923. Various types of experiments indicate a "stroke volume" of the heart of 1.5 to 2 cc. per kilo body weight, maintained with a fair degree of constancy. In the effort to find a simple satisfactory method to measure cardiac output, Y. Henderson and H. Haggard (Amer. J. Physiol., 73: 193, 1925) propose the determination of the rate of absorption of a slightly soluble gas, suggesting ethyl iodide. The difference between the ethyl iodide content of inspired and expired air times the minute-volume of respiration gives the minute-volume of the gas absorbed. The alveolar concentration times the coefficient of solubility gives the

Meanwhile I know and state to all that the blood is transmitted sometimes in a larger amount, other times in a smaller, and that the blood circulates sometimes rapidly, sometimes slowly, according to temperament, age, external or internal causes, normal or abnormal factors, sleep, rest, food, exercise, mental condition, and such like.

But suppose even the smallest amount of blood be transmitted through the lungs and heart at a single beat, a greater quantity would eventually be pumped into the arteries and the body than could be furnished by the food consumed,[3] unless by constantly making a circuit and returning.

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amount in arterial blood. The minute-volume absorbed divided by the arterial concentration gives the volume flow per minute through the lungs, which divided by the pulse-rate gives the "stroke-volume" of the heart. See also the Lancet, 2: 1265 and 1317, Dec. 19 and 26, 1925. The problem may also be solved in a relatively simple mechani cal way, by x-ray pictures of the heart at systole and diastole (W. J. Meek and J. A. E. Eyster, Amer. J. Roentgenol., 7: 471, 1920; Amer. J. Physiol., 63: 400, 1923; P. Hodges and J. Eyster, Amer. J. Roentgenol., 12: 252, 1924). The next paragraph is an astonishing assertion to make, and we are left to wonder how much of our supposed recent knowledge of the physiology and pathology of the circulation Harvey anticipated. The question regarding ventricular emptying, of fundamental importance in cardiac pathology, is implied in the second paragraph back, where it is indicated that there may be variations in the relative quantities expelled.

[3] This was the crux of the argument to Harvey, since the Galenists insisted that blood was formed in the liver ("natural spirits") from the food consumed, and distributed by the veins to nourish the parts of the body according to their needs. Hence the emphasis placed by Harvey in proving, by most conservative estimates, that the heart pumps in a relatively short time more blood than is needed for nutrition or than food can supply, more in fact than the whole weight of the man or animal. Obviously it must be the same blood going around

The matter is obvious in animal experimentation. If an opening be cut not only in the aorta, but even in a small artery, as Galen claims, in man, the whole blood content may be drained from the entire body, from veins as well as arteries, in almost half an hour's time.

Butchers can also well enough confirm this point. In killing an ox by cutting the arteries of the neck, the whole mass of blood may be drained off and all the vessels emptied in less than a quarter of an hour. We know how quickly an excessive hemorrhage may occur in removing a tumor or in an amputation.

The force of this argument would not be lost by saying that blood flows equally if not more from veins than from arteries, in butchering or amputating. The contrary of this really holds. Because they collapse, and have no power to propel blood, and because there is a block where the valves are placed, as shall be shown later, the veins really pour out little blood. The arteries, however, squirt it out in quantities, with force, as if ejected from a syringe. The matter may be tested by cutting the artery in the neck of a sheep or dog, but leaving the vein alone, and it will easily be seen with how much force, in what amounts, and how quickly all the blood in the body is drained, from veins as well

and around. The introduction of quantitative evidence into physiological problems was Harvey's great philosophical contribution, and he apparently realized it, for he uses it again and again with telling effect.

as arteries. The arteries receive blood from the veins in no other way than by transmission through the heart, as previously said. So by ligating the aorta close to the heart, there need be no uncertainty about finding the arteries empty if they be opened in the neck or elsewhere, and the veins filled.

The reason is now apparent why so much blood is found in the veins in anatomical dissection, and so little in the arteries, so much in the right side of the heart, so little in the left. This fact probably led the ancients to believe that arteries contained only spirits during an animal's life. The reason for the difference is probably as follows.[4] There is no other passage from the veins to the arteries except through the heart and lungs, so when an animal expires and the lungs stop moving, the blood is prevented from passing from the pulmonary artery to the pulmonary vein and then into the left ventricle of the heart. This is like what was noted previously in the embryo, where the transit is prevented by the lack of motion in the lungs and the opening and closing of its tiny pores. The heart, however, does not stop at the same time

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[4] One reason has already been given. Is this an interpolation, or addition to the original draft? There is much evidence that the book was not composed as a whole, but that it is a combination of many scattered notes written at different times. Respiration is quite a factor in maintaining circulation. Dr. R. M. Waters, well-known anesthetist, has told me of several instances where artificial respiration has maintained a circulation when the heart has failed.

as the lungs, but outlives them and continues to beat. The left ventricle and the arteries continue to send blood to the rest of the body and into the veins, but, receiving none from the lungs, they soon become empty.

This fact awakens not a little belief in our position, since it can be ascribed to no other reason than what we have proposed.

It further appears that the greater or more vehemently the arteries pulsate, the quicker will the body be exhausted of its blood in a hemorrhage. Hence in fainting or alarm, when the heart beats slowly and feebly, a hemorrhage is reduced or stopped.

This is also why one cannot draw forth by any effort more than half the blood by cutting the jugular or femoral veins or arteries in a dead body after the heart stops beating. Nor may a butcher succeed in bleeding an ox after hitting it on the head and stunning it, if he does not cut its throat before the heart stops beating.

Finally, it may now be suspected why no one so far has said anything to the point on the place, manner, or purpose of the anastomosis of veins and arteries. I shall now discuss this point.[5]

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[5] But he doesn't. This point is quite forgotten. Further evidence of assembling the treatise from notes written at different times.

Chapter X

The First Proposition, Concerning the Amount of Blood Passing from Veins to Arteries, During the Circulation of the Blood, is Freed from Objections, and Confirmed by Experiments

WHETHER the matter be referred to calculation or to experiment and dissection, the important proposition has been established that blood is continually poured into the arteries in a greater amount than can be supplied by the food. Since it all flows past in so short a time, it must be made to flow in a circle.

Someone may say here that a great amount may flow out without any necessity for a circulation and that it all may come from the food. An example might be given in the rich milk supply of the mammae. A cow may give three or four, or even seven and more gallons of milk daily, and a mother two or three pints when nursing a baby or twins, all of which must obviously come from the food. It may be replied that the heart, by computation, does more in an hour or less.

Not yet persuaded, one may still insist that cutting an artery opens a very abnormal passage through

which blood may forcibly pour, but that nothing like this happens in the intact body, with no outlet made. With the arteries filled, in their natural state, so large an amount cannot pass in so short a time as to make a return necessary. It may be replied that from the computation and reasons already given, the excess contained in the dilated heart in comparison with the constricted must be in general pumped out with each beat and this amount must be transmitted, as long as the body is intact and in a natural state.

In serpents and certain fishes by ligating the veins a little below the heart, you will see the space between the ligature and the heart quickly become empty. So, unless you deny what you see, you must admit the blood returns to the heart. This will be clear later in discussing the second proposition.

We may close here with a single conclusive example, by which anyone may be convinced by his own eyes.

If a live snake be cut open, the heart may be seen quietly and distinctly beating for more than an hour, moving like a worm and propelling blood when it contracts longitudinally, for it is oblong. It becomes pale in systole, the reverse in diastole, and almost all the other things we have mentioned as proving the truth may be clearly observed, for here all happens slower and more distinctly. This especially may be seen more clearly than the midday sun. The vena cava enters at the lower part of the

heart, the artery leaves at the upper. Now, pinching off the vena cava with a forceps or between finger and thumb, the course of blood being intercepted some distance below the heart, you will see that the space between the finger and the heart is drained at once, the blood being emptied by the heart beat. At the same time, the heart becomes much paler even in distention, smaller from lack of blood, and beats more slowly, so that it seems to be dying. Immediately on releasing the vein, the color and size of the heart returns to normal.

On the other hand, leaving the vein alone, if you ligate or compress the artery a little distance above the heart, you will see the space between the compression and the heart, and the latter also, become greatly distended and very turgid, of a purple or livid color, and, choked by the blood, it will seem to suffocate. On removing the block, the normal color, size, and pulse returns.

This is evidence of two kinds of death, failure from a lack, and suffocation from excess. In these examples of both, one may find proof before his eyes of the truth spoken about the heart.

Chapter XI

The Second Proposition is Proven

OUR second proposition may appear more clearly by considering certain experiments from which it is obvious that blood enters a limb through the arteries and returns through the veins, that the arteries are the vessels carrying blood from the heart and the veins the channels returning it to the heart, and that, in the extremities, blood passes from arteries to veins directly by anastomosis or indirectly through pores in the flesh, as discussed before in regard to its transfer from veins to arteries in the heart and thorax. From this it may be clear that it moves in a circle from the center to the extremities and back from the extremities to the center.

Then, making certain calculations, it will also be clear that the quantity may neither be supplied from the food taken in nor necessarily be required for nutrition.

These experiments will also clear up some points regarding ligatures: why they may cause swelling, which is neither by heat nor suction nor any reason yet known; what uses and advantages may be obtained from them in practice; how they may either suppress or provoke hemorrhage; how they

may cause gangrene in the limbs, and what their function may be in castrating animals or removing fleshy tumors.

Because no one has understood the rationale of these matters, it has happened that almost everyone recommends ligatures in treating disease on the authority of the ancients, and very few use them properly or get any benefit from them.

Some ligatures are tight, others middling. I call a ligature tight when it is pulled so firmly about a limb that the beat of the artery cannot be felt beyond it. We use this kind in amputations to control bleeding. This kind is also used in castrating animals and removing tumors, where we see the testicles and tumors dying and dropping off because the ligature keeps out heat and nourishment.

I call a ligature middling which compresses a limb on all sides, but without pain, so that the artery may still pulsate somewhat beyond the ligature. This type is used for "drawing," in blood-letting. The proper ligature for phlebotomy is applied above the elbow in such a manner that the artery at the wrist may still be felt beating slightly.

Now, let an experiment be made on a man's arm, using a bandage as in blood-letting, or grasping tightly with the hand.[1] The best subject is one

[1] These interesting experiments, discussed in a quantitative way in Chapter XIII, imply some of the factors involved in arterial and venous blood pressure. Attention was sharply drawn to the mechanical relations of blood-pressure by the Rev. Stephen Hales (1677–1761) and

who is lean, with large veins, warm after exercise when more blood is going to the extremities and the pulse is stronger, for then all will be more apparent.

Under these conditions, place on a ligature as tightly as the subject can stand. Then it may be observed that the artery does not pulsate beyond the bandage, in the wrist or elsewhere. Next, just above the ligature the artery is higher in diastole and beats more strongly, swelling near the ligature as if trying to break through and flood past the barrier. The artery at this place seems abnormally full. The hand, however, retains its natural color and appearance. In a little time it begins to cool a bit, but nothing is "drawn" into it.

After this bandage has been on for some time, loosen it to the medium tightness used, as I said, in blood-letting. You will see the whole hand at once become suffused and distended, and its veins become swollen and varicosed. After ten or fifteen

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experimental measurements reported in his *Statistical Essays*: *Haæmodynamics*, 1733. A valuable account of Hales has been given by P. M. Dawson (Johns Hopkins Hosp. Bull., 15: 185, 232, 1904). Further advance was made by J.-L.-M. Poiseuille (1799–1869), whose haemodynamometer was introduced in 1828, and whose studies on capillary flow appeared in 1840 (Compt. rend. Acad. sc., 11: 961.1041). In 1847 Carl Ludwig (1816–1895) invented the graphic method of recording blood-pressure, and thus greatly facilitated all phases of physiological analysis (Müller's Arch. Anat. Physiol., 1847, p. 242). A method for determining venous pressure in man was devised by J. A. E. Eyster and D. Hooker (Johns Hopkins Hosp. Bull., 19: 274, 1908). For a general disussion, see W. H. Howells' *Physiology*, 10th Ed., Phila., 1927, p. 475. Also *Journ. Am. Med. Asso.*, 91: 31 (July 7) 1928.

beats of the artery you will see the hand become impacted and gorged with a great amount of blood "drawn" by this medium tight ligature, but without pain, heat, horror of a vacuum or any other cause so far proposed.

If one will place a finger on the artery as it beats at the edge of the bandage, the blood may be felt to flow under it at the moment of loosening. The subject, also, on whose arm the experiment is made, clearly feels, as the ligature is slackened, warmth and blood pulsing through, as though an obstacle has been removed. And he is conscious of it following the artery and diffusing through the hand, as it warms and swells.

In the case of the tight bandage, the artery is distended and pulsates above it, not below; in the mediumly tight one, however, the veins become turgid and the arteries shrink below the ligature, never above it. Indeed, in this case, unless you compress these swollen veins very strongly, you will scarcely be able to force any blood above the ligature or cause the veins there to be filled.

From these facts any careful observer may easily understand that blood enters a limb through the arteries. A tight bandage about them "draws" nothing, the hand keeps its color, nothing flows into it, neither is it distended. With a little slackening, as in a mediumly tight ligature, it is clear that the blood is instantly and strongly forced in, and the hand made to swell. When they pulsate, blood

flows through them into the hand, as when a medium bandage is used, but otherwise not, with a tight ligature, except above it. Meanwhile, the veins being compressed, nothing can flow through them. This is indicated by the fact that they are much more swollen below the bandage than above it, or than is usual with it removed, and that while compressed they carry nothing under the ligature to the parts above. So it is clear that the bandage prevents the return of blood through the veins to the parts above it and keeps those below it engorged.

The arteries, however, for the simple reason that they are not blocked by the moderate ligature, carry blood beyond it from the inside of the body by the power and impulse of the heart. This is the difference between a tight and medium bandage, the former not only blocks the flow of blood in the veins but also in the arteries, the latter does not impede the pulsating force from spreading beyond the ligature and carrying blood to the extremities of the body.

One may reason as follows. Below a medium bandage we see the veins become swollen and gorged and the hand filled with blood. This must be caused by blood passing under the ligature either in veins, arteries or tiny pores. It cannot come through the veins, certainly not through invisible ducts, so it must flow through the arteries, according to what has been said. It obviously cannot flow through the veins since the blood cannot be squeezed back

above the ligature unless it is completely loosened. Then we see the veins suddenly collapse, discharging themselves to the part above, the hand loses its flush, and the stagnant blood and swelling quickly fade away.

Further, he whose arm has been bound for some time with a medium bandage, and whose hand has been rendered somewhat swollen and cold, feels, as the ligature is loosened, something cold creeping up with the returning blood to the elbow or armpit. I think this cold blood returning to the heart, after removing the bandage in blood-letting, is a cause of fainting, which we sometimes see even in robust persons, usually when the ligature is removed, or, as is commonly said, when the blood turns.

Moreover, immediately on loosening a tight bandage to a medium one, we see the veins below it, but not the arteries, swollen with blood continually carried in by the arteries. This indicates that blood passes from arteries to veins, not the reverse, and that there is either an anastomosis of these vessels or pores in the flesh and solid parts permeable to blood. It also indicates that the veins inter-communicate, since, with a medium ligature above the elbow, they all swell up at the same time, and, if even a single venule be cut with a lancet, they all quickly shrink, giving up their blood to this one, and subside almost together.

Anyone may understood from this the reasons for the "drawing" power existing in ligatures, and

perhaps in all fluxes. It is clear how the blood cannot escape from the hand when the veins are compressed with what I call a medium bandage, but being driven in by the heart beat through the arteries, and not being able to escape anywhere, the part must necessarily become gorged and swollen.

How can it be otherwise? Heat, pain, and the suction of a vacuum have a certain "drawing" power to fill a part, but not to distend or swell it abnormally, nor to overcome it so suddenly and powerfully by impact of blood that the flesh and vessels are in danger of being torn or ruptured. It is neither believable nor demonstrable that heat, pain, or the *vis vacui* can do this.

Furthermore, this "drawing" power occurs in a ligature without pain, heat, or the suction of a vacuum. If pain happens to "draw" any blood, with the arm tied above the elbow, how may the hand and fingers and their veins become swollen below the ligature, since because of its pressure, blood cannot get there through the veins? And why is neither swelling, nor sign of venous filling or engorgement, nor any vestige of "drawing" apparent above the ligature?

The obvious cause of the "drawing" or abnormal swelling in the hand and fingers below the bandage is the forceful and copious influx of blood which cannot escape. Indeed, is not the cause of all tumors and oppressive swellings, what Avicenna says, that

the way in is open but the way out closed, so there must be an engorgement or tumor?

May not this happen in boils? As long as the swelling is increasing and has not come to a final state, a full pulse may be felt in the area, especially in more acute tumors in which the swelling is sudden. But these are for later investigation. However, this happened in an accident I experienced. I was thrown once from a carriage and struck my head at a place where an arterial branch crosses the temporal region. Immediately I felt, in the space of about twenty pulsations, a tumor the size of an egg but without either heat or great pain. It seems the blood was pushed out with an unusual amount and speed because of the nearness of the artery to the place of injury.

Now it also appears why, in phlebotomy, if we wish the blood to flow longer and with greater force, we ligate above the cut, not below. If such a flow would come through the veins above, the ligature would not only be of no aid, but would positively hinder it, for if blood flowed downwards from the upper part of an extremity through the veins, it would more properly be tied below the cut so the impeded blood would escape through the cut more abundantly. But since it is forced elsewhere through arteries into the veins lower down, from which return is prevented by the ligature, the veins swell, and being under tension can eject their contents through the opening to some

distance with unusual force. When the bandage is loosened, and the returning channels opened, the flow sinks to not more than a drop at a time. Everyone knows in performing phlebotomy that if you either loosen the bandage, tie below the cut, or bind the limb too tightly, the blood will escape without force, because in the latter the influx of blood through the arteries is blocked by the tightness of the ligature, while in the former the venous return is not properly checked because of its looseness.

Chapter XII

That There is a Circulation of the Blood Follows from the Proof of the Second Proposition

SINCE these things are so, it establishes the proof of what I said previously, that blood continually passes through the heart. For we have seen that blood spreads from the arteries to the veins, not from veins to arteries; we have seen further that almost the total amount of blood can be taken from an arm if a single cutaneous vein be opened with a lancet and a bandage properly applied, and we have seen still further, that there is so much force behind it, and so sufficient a flow that the blood may easily and quickly be withdrawn not only in the amount present in the arm below the ligature before the cut was made, but in the whole arm, and in the entire body, arteries as well as veins.

So it must be admitted, first, that blood is supplied with force and impetus to push it beneath the ligature, for it escapes with vigor, which is derived from the pumping action of the heart and from this alone. Likewise, it must be further admitted that this flow comes from the heart, and by way of the

heart, by a transfer accomplished from the great veins, since it passes through the arteries beneath the ligature, not through veins, and arteries never receive blood from veins except by way of the left ventricle of the heart. Nor could any such an amount be drawn from a single vein anywhere, a bandage being applied above it, especially with such force, such an amount, or so easily and quickly, except by the beating power of the heart in the manner described.

If these things are so, we may very readily compute the amount of blood and come to some conclusion on its circular motion. If, for instance, in phlebotomy, one were to let the blood flow with its usual force and rate for a half hour, there is no doubt but that the greater part of it would be drained off, practically emptying not only arteries but also the great veins, and that fainting and syncope would follow. It is reasonable to assume that as great an amount of blood as is lost in this half hour's time, passed from the great veins through the heart to the aorta. Further, if you figure how many ounces of blood flow through a single arm, or pass under a medium bandage in twenty or thirty heart-beats, you will have a basis for estimating how much flows through the other arm in the same time, or through both sides of the neck, or through both legs, and through all the other arteries and veins of the body. Since all these are continually supplied with fresh blood, which must flow through

the lungs and ventricles of the heart, from the veins, it must be accomplished in a circuit, since the amount involved is much more than can be furnished from the food consumed, or than is needed for the nourishment of the parts.

It is further to be observed that this truth is often demonstrated in blood-letting. Though you properly bandage the arm, and puncture the vein correctly with a lancet, if a fainting state of mind comes on through fear or any other cause, and the heart beats more sluggishly, blood will escape only a drop at a time, especially if the ligature be made a little more tight. The reason is that the feeble beat in the compressed artery, with the weaker propelling power, cannot force the blood under the bandage.[1] For the same reason the feeble and languid heart cannot force the normal amount of blood through the lungs or transfer it from the veins to the arteries. In the same way and for the same reasons, it happens that the menses of women and all types of hemorrhages are checked. If the opposite occurs, the patient recovering his mind, and losing his fear, you will see the arteries at once beat more powerfully, even in the bound-off part, so the blood gushes from the opening and flows steadily.

[1] A characteristic example of Harvey's clear reasoning. It is easily inferred that the obvious factor in maintaining blood pressure is the pumping action of the heart.

Chapter XIII

The Third Proposition is Proven, and the Circulation of the Blood is Demonstrated from it

SO FAR we have considered the amount of blood flowing through the heart and lungs in the body cavity, and similarly from the arteries to the veins in the periphery. It remains for us to discuss how blood from the extremities gets back to the heart through the veins, and whether or not these are the only vessels serving this purpose. This done we may consider the three basic propositions proving the circulation of the blood so well established, so plain and obvious, as to force belief.

This proposition will be perfectly clear from a consideration of the valves found in the venous cavities, from their functions, and from experiments demonstrable with them.

The celebrated anatomist, Hieronymus Fabricius of Aquapendente, or, instead of him, Jacobus Sylvius, as Doctor Riolan wishes it, first described membranous valves in the veins, of sigmoid or semilunar shape,[1] and being very delicate eminences

[1] Hieronymus Fabricius of Aquapendente (1537–1619) was a pupil of G. Fallopius (1523–1562) who was in turn the pupil of Vesalius (1514–1564). It was their establishment of modern anatomy

on the inner lining of these vessels. They are placed differently in different individuals, but are attached to the sides of the veins, and they are directed upwards toward the main venous trunks. As there are usually two together, they face and touch each other, and their edges are so apt to join or close that they prevent anything from passing from the main trunks or larger veins to the smaller branches. They are so arranged that the horns of one set are opposite the hollow part of the preceding set, and so on alternately.

The discoverer of these valves and his followers did not rightly appreciate their function. It is not to prevent blood from falling by its weight into areas lower down, for there are some in the jugular vein which are directed downwards, and which prevent blood from being carried upwards. They are thus not always looking upwards, but more correctly, always towards the main venous trunks and the

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which gave such glory to Padua where they taught. Harvey studied under Fabricius from 1598 to 1602. Vesalius was a pupil of J. Sylvius (1478–1555) at Paris.

It is likely that G. Canano (1515–1578) first described the valves in the veins. C. Estienne (d. 1564) had observed valves in the portal veins (not present in man) in 1538, and J. Sylvius commented on them posthumously. The first published drawings of venous valves were by S. Alberti, *De Valvulis*, 1585, who acknowledged indebtedness to Fabricius. The latter demonstrated them publicly in 1579 and published his *De venarum osteolis* in 1603. Harvey employed to make his two plates the same Frankfort craftsman who had made the copper-plates for the 1624 edition of Fabricius (H. Cushing and E. C. Streeter, *Monumenta Medica, IV, Canano*, Florence, 1925). For a comprehensive historical survey of valves in veins, see Franklin, K. J., Proc. Roy. Soc. Med. (Sect. Hist. Med.) 21: 1, 1927.

heart. Others as well as myself have sometimes found them in the milky veins[2] and in the venous branches of the mesentery directed towards the vena cava and portal vein. To this may be added that there are none in the arteries, and that one may note that dogs, oxen, and all such animals have valves at the branches of the crural veins at the top of the sacrum, and in branches from the haunches, in which no such weight effect of an erect stature is to be feared.

Nor, as some say, are the valves in the jugular veins to prevent apoplexy, since the head is more likely to be influenced by what flows into it through the carotid arteries.[3] Nor are they present to keep blood in the smaller branches, not permitting it to flow entirely into the larger more open trunks,

[2] Does Harvey mean the lacteals? The Galenical error, to which Harvey subscribed, that the veins of the mesentery carried chyle to the liver, was cleared up by G. Aselli (1581–1626) who discovered the lacteals (*De lactibus*, Milan, 1627), by J. Pecquet (1622–1674) who showed their passage to the thoracic duct and then to the subclavian vein (*Experimenta nova*, Paris, 1651), and by O. Rudbeck (1639–1702) and T. Bartholin (1616–1680) who discovered the intestinal lymphatics and their connection with the thoracic duct. Pecquet's work contained a carefully devised proof of Harvey's doctrine. On April 28, 1652, Harvey wrote a letter to Dr. R. Morison of Paris (see Willis's translation of Harvey's works, Sydenham Society, 1847, p. 604) in which he discussed Pecquet's contribution. His characteristic conservatism prevented him from accepting the discovery, although it offered a demonstrable explanation of an unsatisfactory portion of his own.

[3] An idea partially expressed in their very name, "the arteries of sleep." This name may have developed from the early observation (used for anesthetic purposes by the Assyrians) that pressure on these vessels might be followed by fainting.

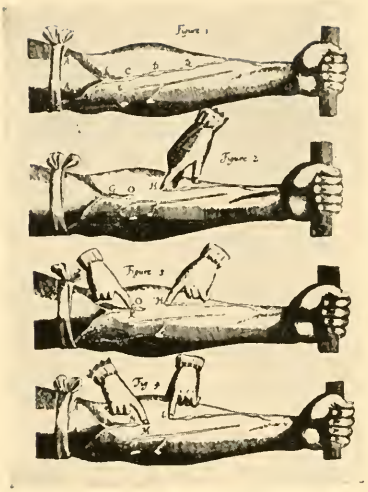
for they are placed where there are no branches at all, although I confess they are more frequently seen where there are branchings. Nor are they present for slowing the flow of blood from the center of the body, for it seems likely it would flow slowly enough anyway, as it would then be passed from larger to smaller branches, become separated from the source and mass, and be moved from warmer to cooler places.

The valves are present solely that blood may not move from the larger veins into the smaller ones lest it rupture or varicose them, and that it may not advance from the center of the body into the periphery through them, but rather from the extremities to the center. This latter movement is facilitated by these delicate valves, the contrary completely prevented. They are so situated that what may pass the horns of a set above is checked by those below, for whatever may slip past the edges of one set is caught on the convexity of those beyond, so it may not pass farther.

I have often noticed in dissecting veins, that no matter how much care I take, it is impossible to pass a probe from the main venous trunks very far into the smaller branches on account of the valvular obstructions. On the contrary it is very easy to push it in the opposite direction, from the branches toward the larger trunks. In many places a pair of valves are so placed that when raised they join in the middle of the vein, and their edges are

so nicely united that one cannot perceive any crack along their junction. On the other hand, they yield to a probe introduced from without inwards and are easily released in the manner of flood-gates opposing a river flow. So they intercept, and when tightly closed, completely prevent in many places a flow of blood back from the heart and vena cava. They are so constituted that they can never permit blood to move in the veins from the heart upwards to the head, downwards toward the feet, or sidewise to the arms. They oppose any movement of blood from the larger veins toward the smaller ones, but they favor and facilitate a free and open route starting from the small veins and ending in the larger ones.

This fact may be more clearly shown by tying off an arm of a subject as if for blood-letting (*A*, *A*, fig. 1). There will appear at intervals (especially in rustics) knots, or swellings, like nodules (*B*, *C*, *D*, *E*, *F*), not only where there is branching (*E*, *F*), but also where none occurs (*C*, *D*). These are caused by the valves, appearing thus on the surface of the hand and arm. If you will clear the blood away from a nodule or valve by pressing a thumb or finger below it (*H*, fig. 2), you will see that nothing can flow back, being entirely prevented by the valve, and that the part of the vein between the swelling and the finger (*H*, *O*, fig. 2), disappears, while above the swelling or valve it is well distended (*O*, *G*). Keeping the vein thus empty of blood, if



Experiments on a bandaged arm

you will press downwards against the valve, (*O*, fig. 3) by a finger of the other hand on the distended upper portion (*K*, fig. 3), you will note that nothing can be forced through the valve. The greater effort you make the more the vein is distended toward the valve, but you will observe that it stays empty below it (*H*, *O*, fig. 3).

From many such experiments it is evident that the function of the valves in the veins is the same as that of the three sigmoid valves placed at the opening of the aorta and pulmonary artery, to prevent, when they are tightly closed, the reflux of blood passing over them.

Further, with the arm bound as before and the veins swollen, if you will press on a vein a little below a swelling or valve (*L*, fig. 4) and then squeeze the blood upwards beyond the valve (*N*) with another finger (*M*), you will see that this part of the vein stays empty, and that no back flow can occur through the valve (as in *H*, *O*, fig. 2). But as soon as the finger (*H*) is removed, the vein is filled from below (as in *D*, *C*, fig. 1). Thus it is clearly evident that blood moves through the veins toward the heart, from the periphery inwards, and not in the opposite direction. The valves in some places, either because they do not completely close, or because they occur singly, do not seem adequate to block a flow of blood from the center, but the majority certainly do. At any rate, wherever they seem poorly made, they appear to be compensated

for in some way, by the greater frequency or better action of the succeeding valves. So, as the veins are the wide open passages for returning blood to the heart, they are adequately prevented from distributing it from the heart.

Above all, note this. With the arm of your subject bound, the veins distended, and the nodes or valves prominent, apply your thumb to a vein a little below a valve so as to stop the blood coming up from the hand, and then with your finger press the blood from that part of the vein up past the valve (*L*, *N*, fig. 4), as was said before. Remove your thumb (*L*), and the vein at once fills up from below (as in *D*, *C*, fig. 1). Again compress with your thumb, and squeeze the blood out in the same way as before (*L*, *N*, and *H*, *O*), and do this a thousand times as quickly as possible. By careful reckoning, of course, the quantity of blood forced up beyond the valve by a single compression may be estimated, and this multiplied by a thousand gives so much blood transmitted in this way through a single portion of the veins in a relatively short time, that without doubt you will be very easily convinced by the quickness of its passage of the circulation of the blood.

But you may say this experiment of mine violates natural conditions. Then if you will take as long a distance from the valve as possible, observing how quickly, on releasing your thumb, the blood wells up and fills the vein from below, I do not doubt but that you will be thoroughly convinced.

Chapter XIV

Conclusion of the Demonstration of the Circulation of the Blood

BRIEFLY let me now sum up and propose generally my idea of the circulation of the blood.

It has been shown by reason and experiment that blood by the beat of the ventricles flows through the lungs and heart and is pumped to the whole body. There it passes through pores in the flesh into the veins through which it returns from the periphery everywhere to the center, from the smaller veins into the larger ones, finally coming to the vena cava and right auricle. This occurs in such an amount, with such an outflow through the arteries, and such a reflux through the veins, that it cannot be supplied by the food consumed. It is also much more than is needed for nutrition. It must therefore be concluded that the blood in the animal body moves around in a circle continuously, and that the action or function of the heart is to accomplish this by pumping. This is the only reason for the motion and beat of the heart.

Chapter XV

The Circulation of the Blood is Confirmed by Plausible Methods

IT WILL not be irrelevant here to point out further that even according to common ideas, the circulation is both convenient and necessary. In the first place, since death is a dissolution resulting from lack of heat, all living things being warm, all dying things cold (*Aristotle, De Respir., lib. 2 & 3, De Part. Animal., etc.*), there must be a place of origin for this heat. On this hearth, as it were, the original native fire, the warming power of nature, is preserved. From this heat and life may flow everywhere in the body, nourishment may come from it, and on it all vegetative energy may depend.

That the heart is this place and source of life, in the manner just described, I hope no one will deny.

The blood, then, must move, and in such a way that it is brought back to the heart, for otherwise it would become thick and immobile, as Aristotle says (*De Part. Animal., lib. 2*), in the periphery of the body, far from its source. We note that motion always generates and preserves heat and spirit, while in quietness they disappear. So the blood, in the extremities, thickens from the cold

and loses its spirit, as in death. Thus it must come back to its source and origin to take up heat or spirit or whatever else it needs to be refreshened.

We often see the extremities so chilled by a cold atmosphere that the hands, nose, and cheeks seem deathly blue. The blood in them, stagnating as in the lower parts of a corpse, become livid. The limbs are sluggish and are moved with difficulty, so that they seem almost deprived of life. In no other way can they recover heat, color, and life so completely and especially so quickly as by a freshly driven flow of heat from the source. But how can they, when heat and life are almost gone, draw anything into them? How can they, filled with congealed stagnant blood, admit fresh blood and nourishment, unless they give up their old contents? Thus the heart really is the center where this exhausted blood recovers life and heat, as Aristotle says (*De Respirat., lib. 2*). New blood imbued with heat and spirit by it and sent out through the arteries, forces onwards the chilled and stagnant stuff, and the failing warmth and vitality is restored in all parts of the body.

Hence as long as the heart is uninjured, life and health can be restored to the body generally, but if it is exhausted or harmed by any severe affliction, the whole body must suffer and be injured.[1] When-

[1] This sentence is the one clear note in a chapter badly fogged by speculations based on the traditional natural philosophy. Note the rather weak illustration from a field in which the footing is still

ever the source is damaged, nothing, as Aristotle says (*De Part. Animal., lib. 3*), can help it or anything depending on it. Perhaps, by the way, this is the reason why anguish, love, jealousy, worry, and similar mental states are accompanied by emaciation, wasting away, and other bodily changes predisposing to disease and consumption in men. A mental disturbance provoking pain, excessive joy, hope or anxiety extends to the heart, where it affects its temper, and rate, impairing general nutrition and vigor. It is no wonder many serious diseases thus gain access to the body, when it is suffering from faulty nourishment and lack of normal warmth.

Further, since all animals live by food digested internally, the distribution of this concoction must be achieved, and hence there must be a place where the aliment is perfected and from which it is apportioned to the separate members. This place is the heart. It is the only organ containing blood

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very uncertain. Harvey was apparently quite interested in the mind-body problem as may also be noted in his *De generatione*, 1651. How was it that he failed to pick up valvular lesions of the heart in his many autopsies? Certainly to so keen an observer the effects of an insufficient or stenotic value would have been obvious, in the light of his discovery. But these significant aspects of cardiac pathology had to wait a couple more centuries to be appreciated. The ancient Greeks commented upon the obvious effects of strong emotion on cardiac action. This may have been one reason why Empedocles and Aristotle made the heart the abiding place of thought. Even the ancient Jewish scribe wrote that "every imagination of the *thoughts of his heart* was only evil" (Genesis 6:5).

for general use, referring not to that specifically used in the coronary arteries and veins, but to the general reserve in the cavities of its auricles and ventricles, since all the others have a blood supply for their own particular use. The heart alone is so situated and constructed as a reservoir and fountain that blood may be apportioned from it and distributed by its beat to all regions according to the size of the artery serving them.

Moreover, force and effort, such as given by the heart, is needed to distribute and move the blood this way. Blood easily concentrates toward the interior, as drops of water spilled on a table tend to run together, from such slight causes as cold, fear, or horror. It also tends to move from the tiny veins to the intermediate branches and then to the larger veins because of the movements of the extremities and the compression of muscles. So it is more inclined to move from the periphery toward the interior, even though valves offered no opposition to the contrary. Therefore, blood requires force and impulse to be moved from its origin against its inclination into more narrow and cooler channels. Only the heart can furnish this, and in the manner already described.

Chapter XVI

The Circulation of the Blood is Supported by its Implications

ASSUMING the truth of this proposition there are certain consequences which are useful in coaxing belief *a posteriori*. Although some of them may seem to be clouded in considerable doubt, a reasonable case may easily be made for them.

How does it happen that in contagious conditions like poisoned wounds, bites of serpents or mad dogs, or lues, the whole body may become diseased while the place of contact is often unharmed or healed? Lues commonly appears at first with pain in the shoulders and head, or by other symptoms, the genitals meanwhile being uninjured. We know that the wound made by a mad dog may have healed when fever and the rest of the unpleasant symptoms supervene. Without doubt it happens that the contagion, first being deposited in a certain spot, is carried by the returning blood to the heart, from which later it is spread to the whole body.[1]

[1] The usual drainage from the tissues is now considered to be through the lympathics. These pass through nodules of lymphoid tissue in which "the contagion,"—bacteria or other foreign bodies,—

In tertian fever, the cause of the sickness first seeking the heart, lingers about the heart and lungs and causes shortness of breath, sighing and languor. This happens because the vital energy is depressed, and because the blood, driven into the lungs, thickens and cannot pass through, as I have noted in autopsies on those dying during the beginning of the disease. Then the pulse is rapid, feeble, and somewhat irregular. When the heat increases, the blood thins out, and an open passage is made, then the whole body warms, the pulse becomes strong and full during the febrile state, while the abnormal heat kindled in the heart is scattered from there to the body, through the arteries, along with the morbific matter, which is thus naturally dissolved and overpowered.[2]

This may also explain why some medical agents applied to the skin have almost as much effect as if taken by mouth. Colocynth and aloes applied externally move the bowels, cantharides excites

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may be filtered out before the lymph passes into the veins. Harvey's reasoning here gave a new turn to the old humoral pathology, again unfortunately neglected by physicians until long after.

[2] It is interesting, in view of our present conceptions of immune reactions to infectious processes, that Harvey should have implied that fever is a beneficial response in the infected individual. The success of Peruvian or Jesuits' bark,—called cinchona from the Spanish Countess Chinchona, one of the first Europeans to benefit from it (1638),—in relieving malarial fevers, obscured the significance of Harvey's implication until recently. The general feeling developed that the fever should be reduced at any cost. Hence the extraordinary interest with the rise of synthetic organic chemistry in the "antipyretics."

the urine, garlic placed on the feet promotes expectoration, cordials invigorate, and so on.[3] It is not unreasonable to say that the veins take up through their openings some of the things applied externally and carry them in with the blood, not unlike the way in which those in the mesentery absorb chyle from the intestines, and carry it along with blood to the liver.

Blood enters the mesentery through the coeliac, and the superior and inferior mesenteric arteries, and passes to the intestines. From these, along with chyle drawn in by the veins, it is returned by their many ramifications to the portal vein and the liver, and from this to the vena cava.[4] The blood in these veins is the same color and consistency as in other veins, contrary to general opinion.

It is not true that there are two opposite movements in these capillaries, chyle inward and blood outward. To be so must be considered incongruous and improbable rather than constituted by the great wisdom of Nature. If chyle were mixed with blood, the raw with the concocted, in equal parts, no coction, or blood formation would follow. Rather there would be a mixture of the two as in the mingling of wine in water or syrup. But when a very small amount of chyle is added to a lot of blood,

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[3] The factors concerned in skin absorption have attracted much attention since the development of chemical warfare. No studies have been made, that I know of, on the materials mentioned here.

[4] See Note 2, Chapter XIII.

it is more comparable, as Aristotle says, to adding a single drop of water to a cask of wine, or the reverse. Then the total is not a mixture, but remains either wine or water. So in dissecting the mesenteric veins, chyme and blood are not found either separately or mixed, but only the same blood in color and consistency as appears in the other veins. Still, since there is some chyle or unconcocted material, however small, in this, Nature has interposed the liver, in whose winding passages it delays and undergoes more change, lest coming too quickly in the rough to the heart, it suppress vitality.

Hence there is almost no use for the liver in the embryo. The umbilical vein clearly passes right through the liver, with an opening or anastomosis to the portal vein, so that fetal blood returning from the intestines does not flow through the liver, but mixed with maternal blood from the placenta goes to the heart through this umbilical vein. So in the development of the fetus, the liver is among the last parts formed. In the human fetus we often see all the organs fully marked out, even the genitals, while there is still almost no trace of the liver. At the time when all the organs, even the heart, appear white, and there is no sign of redness anywhere except in the veins, you will see nothing where the liver should be except an irregular spot like blood spilled out of a ruptured vein.

In the developing egg there are two umbilical veins, one passing through the liver directly to the

heart from the white of the egg, the other from the yolk ending in the portal vein. The chick is developed and nourished first by the white, then after it is formed and leaves the shell, from the yolk. One may find the yolk in the stomach of a chick many days after hatching, for it serves instead of the milk in other animals.

These matters, however, may be more appropriate to notes on the formation of the fetus, where many problems of the following sort can be discussed. Why is one part formed first, another later? Concerning the origin of organs, whether one may be a cause of another, and much about the heart. Why, as Aristotle points out (*De Part. Animal, Lib. 3*), is it the first to take shape, and seem to have life, motion, and sensation before any other part of the body? Likewise, why does blood appear before anything else, and how does it possess the vital animal principle? How does it desire to be moved here and there, for which reason the heart seems to be provided?

In the same way, speculating on the pulse, why does one kind indicate death, another recovery? In considering all varieties of pulse, what do they signify and why? Likewise, in discussing crises, natural discharges, nutrition, the distribution of nutriment, and fluxes.

Finally, in considering all phases of medicine, physiology, pathology, and therapeutics, I realize how many problems may be answered, how many

doubts removed, and how much obscurity cleared up by the truth and light here given.[5] It opens up a field so vast that were I to scan it further or investigate it more fully this little effort would swell to a huge volume which perhaps would take more than my ability or span of life to finish.

In the following chapter, therefore, reference will only be made to the functions and causes derived from an anatomical study of the heart and arteries. Even here I shall find much which may be explained by my theory, and which in turn will make it more clear. Above all, I wish to confirm and illustrate it by anatomical reasoning.

There is one point, however, which might be noted here, although it belongs more properly in my discussion of the function of the spleen.[6] From

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[5] Did Harvey mean this treatise to be a "preliminary communication?" It seems doubtful that there would be much to add to what is here written or to what may be inferred from it. Harvey probably was honest in the remark here made,—he realized what still could be done but was willing to let others take up the burden, while he himself was anxious to let it drop.

[6] This paragraph seems to have been another after-thought. If Harvey ever wrote a discussion of the function of the spleen, it was apparently lost with his other papers during the plunderings of the Civil War. If this note is an example of the many observations Harvey felt could be made in the light of his doctrine, it would better have been omitted. A typical Galenical argument, straining to find the "design" in nature, this is the antithesis of most of the clear-cut observations and explanations in this book. The majority of these are directly in the modern spirit of simple description with an attempted explanation of the mechanism involved. Harvey was in fact among the first to emphasize the *how* in physiology, rather than the more conceited and arrogant *why*.

the upper part of the splenic branch leading to the pancreas arise the posterior coronary, gastric, and gastroepiploic veins, all of which are spread in many branches on the stomach, like the mesenterics on the intestines. Likewise, into the lower part of this splenic vessel empty the hemorrhoidal veins from the colon and rectum. Through both these venous systems returning blood is poured into the splenic branch, carrying with it from the stomach a crude watery juice not completely chylified, and from the feces a thick earthy material. Both these are appropriately tempered by natural mixture, although difficultly concocted alone, because of opposite defects. Then, diluted by a large amount of warm blood flowing through the spleen from its large artery, the mixture enters the portal of the liver in a better state of preparation. The defects of either extreme are made up and compensated by this arrangement of the veins.

Chapter XVII

The Motion and Circulation of the Blood is Established by What is Displayed in the Heart and Elsewhere by Anatomical Investigation

I DO not find the heart a separate and distinct organ in all animals. Some, called plant-animals, have no heart at all. These animals are colder, have little bulk, are softer, and of uniform structure, such as grubs, worms, and many which come from decayed material and do not preserve their species.[1] These need no heart to impel nourishment to their extremities, for their bodies are uniform and they have no separate members. By the contraction and relaxation of the whole body they take up and move, expel and remove aliment. Oysters, mussels, sponges

[1] Harvey really says "*generated* from decayed material." This idea of spontaneous generation, current from the beginning of philosophical speculation, received its first serious blow from Francesco Redi (1626–1694) in his *Experientia circa generationem insectorum*, Amsterdam, 1671. The final blow, covering microscopic forms of life, was given by L. Pasteur (1822–1895). In his *De generatione animalium*, 1651, Harvey maintained the theory that the organism is not preformed in the ovum, but that it gradually evolves by growth and union of its parts. This, as Garrison says, "subverted the ancient concept that life is engendered out of corruption (or putrefaction)."

and the whole genus of zoophytes or plant-animals have no heart, for the whole body functions as a heart, and the animal itself is a heart.

In almost the entire family of insects we cannot clearly discern a heart because of the smallness of the body. In bees, flies, hornets, and the like, one can see with a magnifying glass something pulsate. Likewise in lice, in which, since they are translucent, you can easily watch, with a magnifying glass[2] for enlarging, the passage of food like a black spot through the intestines.

In bloodless and colder animals as snails, shrimps, and shell-fish there is a pulsating place like a vesicle or auricle without a heart. This may be seen beating and contracting, slowly indeed, and only in the summer or warmer seasons.

In these this part is fashioned because there is need for some impulse to distribute nutriment on account of the variety of separate organs or the denseness of their substance. But the beats are seldom and sometimes entirely fail through cold. This is appropriate to their doubtful nature as they sometimes seem living, sometimes dying, sometimes showing the vitality of animals, sometimes of

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[2] In the miserable little Longhine edition, Bonn, 1697, with the Archbishop's *imprimatur*, the word *microscopia* is inserted. I was using this edition for translating, and was greatly puzzled that Harvey should have employed such a term. When Dr. John F. Fulton kindly sent me a facsimile of the original edition, my difficulties were not over, but just beginning, for I then had to check over my whole translation, to avoid any other such errors!

plants. This seems also to occur in insects which hide away in winter and appear dead or show a vegetative vitality. But that it happens in red-blooded animals[3] as frogs, turtles, or serpents may justly be doubted.

In larger, warmer, red-blooded animals there is need for something with greater power to distribute nourishment. So, to fishes, serpents, lizards, turtles, frogs and such like, a heart is granted with both an auricle and ventricle. Thus it is very true, as Aristotle contended (*De Part. Animal., Lib. 3*), that no red-blooded animal lacks a heart, by whose beat the nourishing liquid is not only stirred up more vigorously than by an auricle, but is propelled farther and more quickly.

In still bigger, warmer, and more perfect animals with more fervent and spiritous blood, a more robust and fleshy heart is needed to pump the nutritive fluid with greater force and speed, on account of the size and density of their bodies. Further, because the more perfect animals need more perfect nourishment and more native heat, that the aliment may be better concocted[4] and delivered,

[3] Harvey just says "blooded animals." The oxygen carrying pigment in invertebrates is not the iron containing hemoglobin but a copper containing hemocyanin, which is not red colored.

[4] It is interesting to watch the valiant groping towards the facts regarding the oxygenation of blood in the lungs. The idea expressed is that in order better to "perfect" blood from the food, more heat is needed for the process in the liver, and, as was generally recognized, a draft of air promoted burning and heating. But the traditional doctrines, which Harvey follows in his teleological speculations

it is convenient for these animals to have lungs and another ventricle to send nouishment through these lungs.

Wherever there are lungs there are two ventricles in the heart, a right and left, and wherever there is a right there is also a left, but not the reverse. I call that the left ventricle which is distinguished by function, not position, the one namely that sends blood to the whole body, not merely to the lungs. This left ventricle seems to comprise the real heart. It is medianly placed, marked with deeper furrows, and made with greater care, so that the heart seems to have been formed for the sake of the left ventricle. The right ventricle is a sort of servant to the left, it does not reach to the apex, its walls are three-fold thinner, and it is somehow joined on to the left, as Aristotle says. Its capacity indeed is greater since it not only furnishes material to the left but also nourishment to the lungs.

It is noteworthy that this is otherwise in the embryo, where there is no such difference between the ventricles. As in the double kernels of a nut, they about equal each other, and the tip of the right reaches the apex of the left, so that the heart appears as a double-pointed cone. Here, as I have said, blood does not pass through the lungs from

through some of the chapters of this book, are full of the many contradictions against which he is so bitter in the Introduction. In the present instance, for example, it was also taught that respiration existed for cooling the heart, to keep the blood from boiling and extinction (Note 3, Chapter VI).

the right side of the heart to the left. Both ventricles equally have the same function of transferring blood from the vena cava to the aorta through the *foramen ovale* and the *ductus arteriosus*, and of pumping it to the whole body, whence their structural equality.

However, when the lungs are used and it is time for the passages spoken of to be closed, then these differences in the ventricles begin to appear, since the right pumps only through the lungs, but the left through the whole body.

There are also so-called braces in the heart, many fleshy and fibrous bands, which Aristotle calls nerves (*De. Respirat. & De Part. Animal., Lib. 3*). They are stretched partly from place to place, and partly in the walls and septum, where they form little pits. Little muscles are concealed in these furrows which are added to assist in a more powerful contraction of the heart and a more vigorous expulsion of blood.[5] Like the clever and elaborate arrangement of ropes on a ship, they help the heart to contract in every direction, driving blood more fully and forcibly from the ventricles.

It may be shown, however, that some animals have less than others, that in all animals with them, they are more numerous and stronger in the left than in the right ventricle, and in some animals where

[5] These *papillary muscles*, elongated into the *chordae tendinae* which extend to the valves, seem to aid in closing the valves more exactly. See Note 5, Chapter II.

they are present in the left, none are found in the right chamber. In man there are more in the left than in the right ventricle, and more in the ventricles than in the auricles, and in some subjects it seems there are none in the auricles. In large, muscular, peasant-type individuals there are many, in more slender frames, and in women, few.

In some animals the ventricles of the heart are smooth inside, entirely without fibers or bands. In almost all small birds, serpents, frogs, turtles, and such like, and in most all fishes, neither fibers, or so-called nerves, nor tricuspid valves are found in the ventricles.

In some animals the right ventricle is smooth inside while the left has these fibrous bands, as in the goose, swan, and heavier birds. The reason is the same here as elsewhere. Since the lungs are spongy, loose, and soft, not so great a force is needed to pump blood through them. Therefore the right ventricle either has none of these fibers or they are few and weak, not fleshy or muscular. Those of the left ventricle, however, are stronger, more numerous, and more muscular because this chamber needs to be more powerful since it must propel blood farther through the whole body. This is also why the left ventricle is placed in the middle of the heart, and has walls three times as thick and strong as the right.

So all animals, man included, that have a stronger and more sturdy frame, with large, brawny limbs

some distance from the heart, have a more thick, powerful, and muscular heart, as is obvious and necessary. On the contrary, those whose structure is more slender and soft have a more flaccid, less massive, and weaker heart, with few or no fibers internally.

Consider likewise the function of the sigmoid valves. These are so made that blood once received into the ventricles of the heart, or sent into the pulmonary artery or aorta, can not regurgitate. When they are raised and tightly joined, they form a three pointed line, like the bite of a leech, and the more tightly they are forced shut, the more do they block the reflux of blood.

The tricuspids are like gate-keepers at the point of inflow from the vena cava and pulmonary vein, so that the blood, when strongly propelled, may not escape back into them. They are not present in all animals, for the reason stated, nor do they seem to have been made with the same efficiency in those in which they are found.[6] In some they are made

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[6] This again raises the question as to whether or not Harvey ever noted insufficiency or stenosis of the valves in humans. He is speaking as an comparative anatomist here.

According to Galen (J. C. Dalton, *Doctrines of the Circulation*, Phila., 1884, p. 250), Erasistratus named the right auriculo-ventricular valves "tricuspids" (*τριγλωχινας*), and also called the valves at the openings of the pulmonary artery and aorta "sigmoid" in shape. Since the old Greek *sigma* had the form of the letter C, this gave a correct impression of their semilunar form. Vesalius, in his immortal *De Humani Corporis Fabrica*, Basle, 1543, p. 592, first likens the left auriculo-ventricular valves to a bishop's miter.

to fit exactly, in others poorly and negligently, so that they may be closed according to the greater or lesser impulse from the contraction of the ventricles. In the left ventricle, therefore, that the closure may be made more complete against the stronger impulse, there are only two, placed like a miter, and lengthened in a conical form so they may come together medianly and close very exactly. This probably led Aristotle to consider this ventricle double, divided transversely. Likewise, that blood may not escape back into the pulmonary vein and thus reduce the power of the left ventricle to pump blood through the whole body, these mitral valves surpass in size, strength, and exactness of closure those placed in the right ventricle. Hence, necessarily, no heart can be found without a ventricle since there must be a source and store-house for blood.

The same does not always hold for the brain.[7] Almost no kind of bird has a ventricle in the brain, as is clear in the goose and swan, whose brains nearly equal in size that of the rabbit. But the rabbit has ventricles in the brain while the goose does not.

Wherever there is a single ventricle in the heart, a flaccid, membranous, hollow, blood-filled auricle is appended. Where two ventricles exist, there are like-

[7] This paragraph and the last sentence of the preceding seem to be unnecessary appendages to the argument. They appear in the middle of a long paragraph which has been broken up for greater ease in reading. Was Harvey implying that there is no necessary store-house for "animal spirits" in the brain as there is for "vital-spirits" (or blood) in the heart?

wise two auricles. On the other hand, in some animals there is an auricle without a ventricle, or anyway a sac like an auricle, or the vein itself, dilated in one place, pulsates. This is seen in hornets, bees, and other insects, in experiments on which I think I can show not only a pulse but also a respiration in that part called a tail. This can be seen to lengthen and contract, sometimes quickly, sometimes slowly, as the insect seems to be blown up and to need more air. But more of this in the Treatise on Respiration.[8]

Likewise it is clear that the auricles beat, contract, and, as I said before, push blood into the ventricles. So wherever there is a ventricle, an auricle is needed. Not alone, as commonly believed, to be a receptacle and store-house for blood. For what use is a pulsation in retaining? The auricles exist as the initial motive power of the blood. Especially the right auricle, the first to live and the last to die, as said before. They are necessary in order to cast the blood conveniently into the ventricles. These, continually contracting, throw out more fully and forcibly the blood already in motion, just as a ball-player can send a ball harder and farther by striking it on a rebound than if he simply throws it. Moreover, contrary to common opinion, neither the heart nor anything else can draw anything into itself by dilating or distending, unless like a sponge previously compressed, while it is return-

[8] If the Treatise on Respiration was written, it was probably destroyed by the Parliamentary soldiers who sacked Harvey's rooms in Whitehall in 1642, when Harvey was with Charles I at Edgehill.

ing to its real condition.[9] All local motion in an animal first takes place from the contraction of some particular part. Thus blood is cast into the ventricles by auricular contraction, as shown before, and then passed on and distributed by the ventricular contraction.

I have been interested in getting at the truth of this matter of local motion. How the initial motivating organ in all animals having a prime motive spirit is, as Aristotle says in his book *De Spiritu*, contractile; how νευρον is derived from νευω (*nuto*, *contraho*), and how Aristotle had more than a superficial acquaintance with muscles, and on that account referred all motion in animals to nerves and a contractile part, and hence called those bands in the heart nerves,—all this I hope to make clear soon, if I am permitted to demonstrate my observations on the organic motion of animals and the structure of muscles.[10]

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[9] According to present physiological conceptions, venous pressure is great enough to open the auriculo-ventricular valves during diastole, so that considerable blood flows into the ventricles while they are relaxed and before the auricles start to contract. It is generally agreed with Harvey that the ventricles have no suction power, but it is felt that the contractions of the auricles force in only a portion of the ventricular contents. See Note 4, Chapter IV.

[10] This treatise also disappeared. The derivation of terms is apparently offered in apology for Aristotle's calling the muscular bands in the heart "nerves." G. A. Borelli (1608–1679), in developing a mechanical analysis of muscular motion carried over a theory of contraction caused by a liquid discharge from nerves (*De motu animalium*, 1680). For a superb discussion of the physiology of muscle consult J. F. Fulton's monograph, Baltimore, 1927.

But to go on with our subject, on the function of the auricles in filling the ventricles with blood, it may be observed that the thicker and denser the walls of the heart itself, the more fibrous and muscular are the auricles, and the reverse. In some animals the auricle appears to be a bloody membranous sac, as in fishes, where it is so delicate and ample that it seems to float above the heart. In other fishes as the carp, and barbel, in which this vesicle is a little more fleshy, it bears a striking resemblance to lungs.

In some men of heavier and huskier build, the right auricle is so robust and so well braced inside by bands and various connecting fibers that it approximates in strength the ventricle of other subjects. I marvel that there is such variation in this in different men.

It is noteworthy that the auricles are disproportionately large in the fetus, because they are present before the rest of the heart is made or can take up its function, so that, as shown before, they assume the duty of the whole heart.

My observations previously referred to on the development of the fetus, and which Aristotle confirms in regard to the egg, throw great light on this matter. While the fetus is till soft like a worm, or, as is said, in the milk,[11] there is a single bloody spot, or pulsating sac, as if a part of the umbilical vein

[11] I can't trace the origin or significance of this expression. My wretched Longhine edition, Bonn, 1697, rendered *vermicules* as *ventricules*, and *lacte* as *lucte*!

were dilated at its base or origin. After awhile when the fetus is outlined and the body begins to be more substantial, this vesicle becomes more fleshy and stronger, and its constitution changing, it turns into the auricles. From these the bulk of the heart begins to sprout, although as yet it has no function. When the fetus is really developed, with bones separated from flesh, when the body is perfected and has motion, then the heart actually beats and, as I said, pumps blood by both ventricles from the vena cava to the arteries.

Thus divine Nature making nothing in vain, neither gives a heart to an animal where it is not needed, nor makes one before it can be used. By the same steps in the development of every animal, passing through the structural stages, I might say, of egg, worm, and fetus, it obtains perfection in each. These points are confirmed elsewhere by many observations on the formation of the fetus.[12]

Hippocrates, in the book *De Corde*, did not call the heart a muscle without good reason.[13] Its action or

[12] Another paragraph stressing the "Bridgewater treatise" idea. Harvey was probably engaged, while this was published, on his other great treatise, *De generatione animalium*, which appeared at the solicitation and under the direction of Dr. George Ent, in London in 1651. This is a remarkable volume, not yet properly annotated or appreciated, a mine of observation and interpretation, and a complete commentary on the ideas of Aristotle and Fabricius on fetal development. As a sustained intellectual effort it surpasses the present volume, and with the development of sexual physiology may be recognized as a very significant contribution.

[13] This little tract of about 800 words (*περι καρδιης*) is the best anatomical work of the Hippocratic Collection. Written about

function is that of a muscle, to contract and to move something, namely its content of blood.

As in the muscles themselves, the actions and uses of the heart may be understood from the arrangement of its fibers and the structure of its movable parts. Anatomists generally agree with Galen that the heart is composed of a variety of fibers arranged straight, transversely, and obliquely. But in the boiled heart the fibers are seen to be arranged otherwise. All those in the walls and septum are circular as in a sphincter whereas those in the bands are longitudinally oblique.[14] So when all these muscles contract simultaneously the apex is pulled toward the base by the bands and the walls are drawn together in a sphere. The heart is contracted on all sides and the ventricles are compressed. Hence it must be recognized that since it acts by contraction, its function is to pump blood into the arteries.

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400 B. C., it describes the auriculo-ventricular and semilunar valves, and the *chordae tendinae*. Air is said to enter the heart and change the blood. The conception of the heart as a muscle is not usually credited either to Harvey or the Hippocratic writer. It is characteristic of Harvey to attempt to fortify his ideas by references to the classical authorities. See Note 3, Chapter II.

[14] Interesting that Harvey boiled the heart to get a clear picture of its fibrous make-up. The best recent analysis of this subject was made by F. P. Mall (Amer. J. Anat., 2: 211, 1911). Mall describes a deep and superficial "bulbospiral" and "sinospiral" system of fibers which curve around from the base to the apex of the heart. These form a sling-like support for the circular fibers which are especially thick on the left side. Harvey's description is essentially correct. See W. H. Howell's *Physiology*, 10th Ed., Phila., 1927.

No less should it be agreed with Aristotle in such questions on the significance of the heart as whether it receives motion and sensation from the brain, or blood from the liver, or whether it is the source of the veins and blood, and so on. Those who try to refute him here overlook or do not understand the significance of his argument. This is, that it is the first to exist, and contains in itself blood, vitality, sensation and motion before the brain or liver are formed, or can be clearly distinguished, or at least before they can assume any function. The heart is fashioned with appropriate structures for motion, as an internal organism, before the body. Being finished first, Nature wished the rest of the body to be made, nourished, preserved, and perfected by it, as its work and home. The heart is like the head of a state, holding supreme power, ruling everywhere.[15] So in the animal body power is entirely dependent on and derived from this source and foundation.

Many points about the arteries further illustrate and confirm this truth. Why doesn't the *arteria venosa* pulsate, since it is considered an artery? Why may a pulse be felt in the *vena arteriosa*?[16] Because

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[15] This is the general Aristotelian position.

[16] The *arteria venosa* is the pulmonary vein, the *vena arteriosa* the pulmonary artery.

In the last sentence of this paragraph my Latin lexicon (E. A. Andrews, New York, 1852) permits me to translate *impetum* literally as pressure, but not *impellentis* as *pumping*! Harvey does not anywhere in the treatise use a word which may literally be translated to give the conception of the heart as a pump. Retaining the tradi-

the pulse in an artery is due to an impact of blood. Why do the arteries differ so much from veins in the thickness and strength of their walls? Because they must withstand the pressure of the pumping heart and rushing blood.

Hence, since Nature makes nothing in vain, and does the best everywhere, the nearer arteries are to the heart the more do they differ from veins in structure. Here they are stronger and more ligamentous,[17] but in their terminal branchings, as in the hands, feet, brain, mesentery, and testicles, they are so similar to veins in make up that it is hard to tell one from another by ocular examination of their tunics. This occurs from the following good reason: the farther an artery is away from the heart the less it is reached by the cardiac pressure dissipated by the long space. Since all the arterial trunks and branches must be filled with blood, the cardiac impulse is further diminished, divided in a way by each branching.

So the terminal arteries appear like veins, not only in structure, but also in function, for they rarely show a perceptible pulse unless the heart beats more violently, or the arteriole dilates or is more open at the particular point.[18] Thus it happens that we may

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tional semi-technical language of the subject, he perhaps never thought of using a word which conveys the meaning he so clearly implies.

[17] This is the nearest Harvey comes to grasping the idea of the elasticity of blood-vessel walls, a factor of considerable importance in determining blood pressure.

[18] A remarkable explanation, implying vaso-constriction and

sometimes be aware of a pulsation in the teeth, fingers or inflammatory tumors, other times not. By this symptom I have diagnosed fever in children, whose pulse is naturally rapid anyway. By holding tightly the fingers of a young and delicate person I can easily perceive pulsation there when the fever is high.

On the other hand, when the heart beats more feebly, as in fainting, hysteria, asphyxia, and in the very weak and moribund, it is impossible to feel a pulse not merely in the fingers, but even at the wrist or temple.

Here, lest they be deceived, surgeons should be advised that when blood flows with force from a wound, in amputations, or in removing a fleshy tumor, it always comes from an artery. Not always in spurts, however, since the small arteries may not pulsate, especially if compressed by a bandage.

Further, here is the same reason why the *vena arteriosa* not only has the structure and walls of an artery but also why it does not differ so much from the veins in the thickness of its walls as the aorta. The latter sustains a greater impulse from the left ventricle, than the former from the right. The walls of the pulmonary artery are softer in structure than those of the aorta to the same extent as the walls and flesh of the right ventricle are weaker than those of

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dilatation, another important factor in determining blood pressure. Harvey correctly notes vascular dilatation in local inflammatory reactions, and cutaneous vascular dilatations in fever.

the left. The lungs are relatively softer in texture than the flesh and bulk of the body in the same degree that the walls of the pulmonary artery differ from those of the aorta. This general proportion holds quite universally. The stronger, more muscular, and more substantial the build of men, the thicker, heavier, more powerful and fibrous the heart, and the auricles and arteries are proportionally increased in thickness, strength, and all other respects.

On the other hand, in fish, birds, serpents, and other such families of animals, the ventricles of the heart are smooth inside, without villi or valves. The walls are thinner and the arteries scarcely differ from the veins in thickness of tunics.

Further, why do the lungs have such large vessels, veins as well as arteries, for the trunk of the pulmonary veins exceeds both crurals and jugulars, and why are they filled with so much blood? We know by experience in autopsies and the advice of Aristotle, not to be deceived by the appearance of such animals as we encounter in dissection which have been bled to death. The reason is that the source and storehouse of the blood, and the place for its perfecting, is in the lungs and heart.

Similarly, why do we find the pulmonary vein and left ventricle in dissections so full of the same black clotted blood which fills the right ventricle and pulmonary artery? Because blood continually traverses the lungs from the right side of the heart to the left.

Finally, why has the so-called *vena arteriosa* the

structure of an artery, while the *arteria venosa* has that of a vein? Because really, in build, in function and everything, the former is an artery, the latter a vein, contrary to what is commonly believed.[19] Why has the pulmonary artery so large an opening? Because it carries much more blood than is needed for the nourishment of the lungs.

All these phenomena and many others noted in dissecting, if correctly judged, seem clearly to illustrate and to confirm the truth announced in this tract, and at the same time to refute popular opinion. Certainly it would be hard to explain in any other way why all these matters are so made and constituted except in a manner conforming to my theory and to what I have expounded.

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[19] Since he so clearly points out the inconsistencies of the current names, why did not Harvey rename these vessels? One may sometimes be too deferential to traditional authority.

APPENDIX I

TRANSLATOR'S POSTSCRIPT

TRANSLATOR'S POSTSCRIPT

Veritas nos liberabit

As far as I can find, this is the third attempt to render Harvey's classic into current English idiom. The first, which I have not seen, was apparently an anonymous effort prefaced by a Zachariah Wood of Rotterdam, and printed by Francis Leach for Richard Lowndes of London, in 1653. This octavo was reprinted in 1673. The second was the well known translation made for the Sydenham Society by Robert Willis and published in 1847. Reprinted in London in 1889, in Canterbury in 1894, and in Everyman's Library in 1907, this has become the standard English version. Although an excellent translation, its stilted and involved phraseology makes it rather difficult reading for those more accustomed to present diction. As Mencken has intimated in connection with similar classics, this greatly interferes with their proper appreciation. From my rather limited experience with medical students and physicians, I am confident that they would welcome the chance to study the works of the great contributors to their profession were these to be offered to them in an attractive and easily readable form.

This prompted Mr. Thomas to suggest, when we discussed a tercentennial edition of Harvey's great book, that a new translation in the language and spirit of our times be attempted. Using Willis as a "pony," this has been an easy and delightful task. In his more scientific passages, Harvey is remarkably terse and snappy, in the current style. In his philosophical discussions he becomes vague and his sentences grow beyond control, but whose do not?

Not possessing a copy of the first edition, the basis of my translation was the miserably printed Longhine edition of 1697, which omits the dedication. Willis's translation of the dedi-

cation has been included here: from it one may get some idea of the Cavalierian grace of his style. After my friend, Dr. John Fulton, kindly sent me a copy of Moreton's privately printed facsimile of the original edition, I found several errors in the text I had used. This fortunately necessitated careful collation, resulting in some corrections in the English version.

The translation is admittedly free, in the deliberate attempt to present Harvey's thought in the current physiological manner. Thus, while Harvey nowhere actually uses a word which may be literally rendered "pump," it is our habit to refer to cardiac action in some such term.

The differences in Harvey's style through the book imply its composition at different times. The introduction is far more vigorous, and in its critical attitude, more characteristically youthful than any of the remaining seventeen chapters. The first chapter, on the other hand, apologizing for the effort, has the grace and dignity of careful deliberation, and closes with a classical quotation reflecting the meditative calm of middle age. The last three chapters add little to the significance of the demonstration. They illustrate the futility of theoretical speculation attempting to reconcile opposing points of view with inadequate data. With microscopical technique undeveloped, Harvey could not see the communications between arteries and veins. He tried later to study the problem by a sort of corrosion method, but failed to find anything resembling an anastomosis except in three obscure places. At the time, he tried to complete his demonstrations by metaphysical arguments based on the traditional teleology. This was the antithesis of the method by which he had achieved such brilliant success in the preceding chapters.

The last of the book seems to have been written some time after the main part of it, when long reflection on the subject had crystalized his opinion. The eighth chapter is similar in style and context to the fifteenth and sixteenth, and was, I think, written at about the same time.

The argument in the other chapters from two to fourteen proceeds with certain characteristics that introduced an entirely new method of approach in physiological problems. These are (1) the careful analysis of phenomena observed (chapters two to five); (2) the devising of experimental procedures to test a proposed hypothesis (chapters ten, eleven, and thirteen), and (3) the startling innovation of quantitative reasoning to prove a proposed theory (chapters nine, ten, and thirteen). Harvey was among the first to use the practical methods of science as we do now: observation, hypothesis, deduction, and experiment. This is neither scholastic Aristotelianism nor Bacon's laborious accumulation of data and its manipulation by the cumbersome tables of the *Novum Organum*. The sixth and seventh chapters, on the pulmonary circulation, are puzzling. There is a good discussion of the comparative and embryological aspects of the subject, and then a peculiar use of the traditional authority of Galen as evidence. One may find almost all kinds of logic in Harvey.

In order to bring out the significance of Harvey's work in regard to our modern knowledge of cardiac function, and to relate it to the slow development of this knowledge, footnotes have been added to the translation. I hope they will appeal to medical students and interested laymen. For specialists in the history of medicine, they may seem superfluous, in spite of my effort to make them as brief and inconspicuous as possible. Most of the information in them has been culled from the standard authorities in physiology and its history. A running account of the development of Harvey's demonstration and its influence was to have been appended, but will have to wait till later. A chronology of his life has been added. For my information and point of view I am indebted to a host of Harvey enthusiasts, Haeser, Willis, Munk, Foster, Dalton, Curtis, Osler, D'Arcy Power, Hemmeter, Garrison, and Singer. For scholarly inspiration I am grateful to Dr. George Sarton, Dr. Percy Dawson, and Dr. William Snow Miller. For cheerful

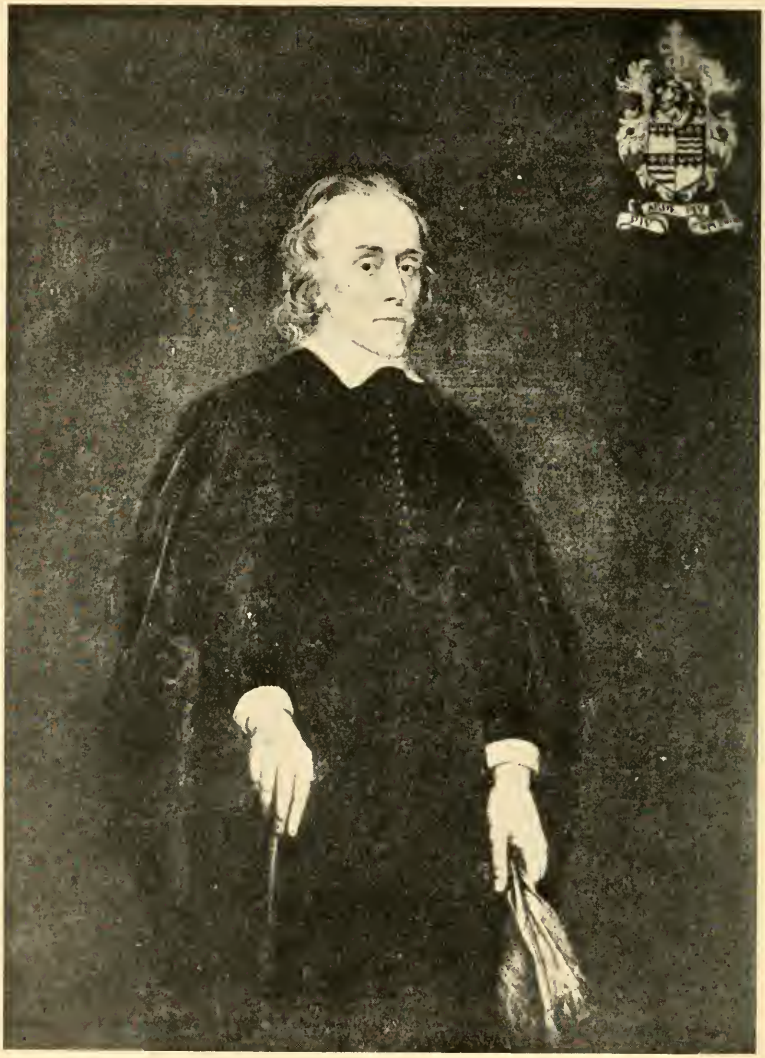
support in this and similar fancies I owe much to my wife's interest, and to that of the genial members of the Dick Marshall Dining Club. I am especially thankful to the Oxford University Press for kind permission to reproduce several of the splendid illustrations from *Portraits of Dr. William Harvey* (1913).

Many efforts are being made this year to celebrate appropriately the tercentennial of the appearance of Harvey's great book. The Royal Society of Physicians of London and the Harvey Society of New York held special festivals. R. Lier and Co. of Florence and the Nonesuch Press are issuing facsimiles of the original work. While these challenge the attention of connoiseurs, this volume has been prepared chiefly in the hope that it may interest medical and advanced zoological students, by offering in a dignified but inexpensive way an opportunity to become acquainted, intellectually, with one of the greatest contributors to their subjects. To that end the publisher and printers have done more than their share to make my little part easy.

It has been a delight to work with Mr. Thomas in the preparation of this volume, and I appreciate his continued courtesy and enthusiasm.

C. D. L.

Madison, Wisconsin
June 13, 1928.



"THE MOST PLEASING PICTURE OF DR. WILLIAM HARVEY"

Usually attributed to Sir Anthony Van Dyck (1599-1641), this dignified painting is in the possession of the heirs of Richard Bright (1789-1858), the celebrated physician to Guy's Hospital. Notethe crest similar to the "stemma" to Harvey at Padua, and the motto, not found elsewhere.

—Courtesy of the Oxford University Press

APPENDIX II

CHRONOLOGY OF THE LIFE OF WILLIAM HARVEY

Chronology *of* William Harvey

1578. Born (April 1) at Folkestone, Kent, of Thomas (a town official) and Joane Hawke Harvey, eldest of "a week of sons, whereof this William was bred to learning, his other brethren being bound apprentices in London, and all at last ended in effect in merchants." (Fuller).

1588. Excitement over and defeat of the Spanish Armada. How thrilled was Harvey entering Canterbury Grammar School this year?

1593. Entered Caius College, Cambridge, implying choice of medical career. Caesalpinus (1524–1603) publishes *Questiones Medicae*, incidentally discussing pulmonary and systemic circulation.

1597. Receives Bachelor's degree from Cambridge. Expedition of Earl of Essex and Sir Walter Raleigh against the Spaniards.

1598. Began medical studies at Padua (in the elite *Universitas juristarum*), scene of the triumphs of Vesalius (1514–1564), R. Columbus (1516–1559), Fallopius (1523–1562), and now of H. Fabricius of Aquapendente (1537–1619), Casserius (1561–1616), Galilei (1564–1642), and Sanctorius (1561–1636). Having just erected a new anatomical theater, Fabricius was loved and respected for his charity, skill, and learning. Harvey apparently became one of his favorite pupils, and even *helped in experiments* (*De generatione*, 6th exercise).

1600. Elected *conciliarius* of "English nation" at Padua. Fabricius publishes his *De formato fetu*. Girodano Bruno burned at Rome. Founding of East India Company. Gilbert's *De magnete*.

1601. Re-elected *conciliarius*. Treason and execution of Earl of Essex.

1602. Awarded diploma (April 25) of Doctor of Physic at Padua, with special notations regarding his skill. Returned to England and received doctorate in medicine from Cambridge. Shakespeare's *Hamlet*.

1603. Publication of Fabricius' *De venarum ostiolis*. Death of Queen Elizabeth, accession of James I.

1604. Admitted a Candidate of the Royal College of Physicians (October 5). Married (November 24) Elizabeth Browne (1580–1645?), daughter of Dr. Lancelot Browne, physician to James I. Lived at St. Martin's, Ludgate. Plague in London.

1605. Death of Mother (November 18) at Folkestone, in her fiftieth year. Death of Father-in-law. Harvey seems to have been well fixed financially. His brothers were wealthy merchants, trading in the Levant. Gun Powder Conspiracy.

1607. Elected Fellow of the Royal College of Physicians (June 5). Settlement of Jamestown, Virginia.

1609. With King's support, sued for the reversion of Physician to St. Bartholomew's Hospital (February 25). Charged as Physician to "Old Bart's" (October 14). Hendrick Hudson anchors the Half-Moon in Hudson River.

1611. King James' Authorized Version of the English Bible.

1613. Elected Censor of the Royal College of Physicians. High cost of living; increasing friction between King and Parliament; religious squabbles. Rise of Puritanism.

1615. Appointed (August 4) Lumleian lecturer, Royal College of Physicians. Detailed duties and salary equivalent to Regius Professorship of Physic at Oxford

or Cambridge (see D'Arcy Power's biography, London, 1897, p. 39).

1616. Delivered (April) first "visceral lecture" at Royal College of Physicians, in manuscript notes in which is his first account of the circulation of the blood. Death of Shakespeare and Cervantes.

1618. Appointed (February 3) Physician Extraordinary to James I, and promised post of Physician in Ordinary as soon as it became vacant. The Lord Chancellor, Francis Bacon, his patient, but no sympathy between them. Start of Thirty Years' War. *Pharmacopoeia Londinensis.*

1620. Publication of Bacon's *Novum Organum.* Puritans settle in New England.

1625. Death of King James I, accession of Charles I.

1627. Appointed (December 3) Elect of Royal College of Physicians, one of eight "directors."

1628. Publication of *Exercitatio anatomica de motu cordis et sanguinis in animalium*, at Frankfort. Elected Treasurer of Royal College of Physicians. Birth of Marcello Malpighi (March 10). Parliament's *Petition of Right.*

1630. Journeys through France and Spain with James Stuart, Duke of Lennox, at King's order. Plagues, wars, and famines. King struggling with Parliament. Appointed Physician in Ordinary to Charles I. Jacob Primrose, licensed to practice with Harvey's consent, publishes first attack on his doctrine of the circulation.

1632. Petitions King to restrict sale of poisons.

1633. Travels with Charles and Court to Scotland. Tactless aggravation of religious animosities. Drew up rules governing St. Bartholomew's Hospital, in which he subordinates surgeons to physicians. Reflection of oppressive court tactics? Recantation of Galilei.

1634. Lancashire witches. Harvey examined and exonerated several suspects.

1635. Accused (November 17) of malpractice by Barber-Surgeons. Revenge? Autopsy report (November 16) on Thomas Parr, reputed to have lived 152 years. Richelieu founded Academie Francaise.

1636. Accompanied Lord Arundel on diplomatic mission to Vienna. Tried to convince Caspar Hoffman at Nuremberg of truth of circulation. Visited Italy. Harvard College founded.

1637. Religious riots in Scotland. Covenanters.

1639. Went with Charles and Lord Arundel against the Scotch.

1640. Sued heirs of Lord Lumley to recover salary. Meeting of Long Parliament. "Grand Remonstrance" against Charles.

1641. Trial and execution of Strafford.

1642. Charles and Court fled London (August). Civil War. Harvey's quarters looted, and valuable papers lost. Death of Galilei. Birth of Newton. Harvey in charge of the Princes (Charles II and James II) at Battle of Edgehill (October), and tends wounded. Browne's *Religio Medici*. Made Doctor of Physic at Oxford (December 7).

1643. Retired from service at St. Bartholomew's. Death of Brothers Matthew and Michael. Taught Charles Scarborough, his successor. Accession of Louis XIV.

1645. Elected Warden of Merton College, Oxford. Did he influence Willis, Highmore, Lower, or Wren? Death of Brother John. Death of wife?

1646. Fled from Oxford with King (April 27). Returned to London.

1648. Retired to live with Brothers Eliab and Daniel. Afflicted with gout. The younger Riolan publishes critique of Harvey's doctrine of the circulation. War of the Fronde. Peace of Westphalia, ending terrible Thirty Years' War, and acknowledging independence of the Netherlands. Sydenham (1624–1689) made bachelor of medicine at Oxford.

1649. Harvey from Cambridge writes two letters to Riolan answering the attack on his demonstration. Execution of Charles I. Cromwell subdues Great Britain and Ireland.

1650. Visited at Christmas time by his friend Dr. George Ent, who obtained manuscript of essay on generation.

1651. Publication of *Exercitationes de generatione animalium*. Offered anonymously to build library for Royal College of Physicians. Pecquet publishes account of thoracic duct. Harvey writes to Dr. Paul M. Slegel, of Hamburg, thanking him for defending his work against Riolan. Meets John Aubrey, his first biographer.

1652. Letter to Dr. R. Morison of Paris criticizing Pecquet's conclusions. Royal College of Physicians placed bust of Harvey in new library.

1653. First English edition of the *De motu cordis*. Parliament disbanded.

1654. Refuses to accept Presidency of Royal College of Physicians.

1657. Died on June 3. Buried in Hempstead Church.

THE BODY OF WILLIAM HARVEY "LAPT IN LEAD"

Deposited in a marble sarcophagus
in the Hempstead Church
by the Royal College of Physicians of London,
St. Luke's Day, 1883.

INDEX

Index

NOTE: Only the English translations and footnotes have been indexed. The reader may readily consult the corresponding portions in the Latin facsimile.

This book—the Leake translation of William Harvey's De Motu Cordis—was set, printed and bound by The Collegiate Press, Menasha, Wisconsin.

The cover design is by The Decorative Designers of Chatham, New Jersey. The front matter was designed and set by The Golden Hind Press of Madison, New Jersey.

The facsimile of the Latin translation is reproduced by a new and exceedingly accurate process in photo-engraving. The type face of the English translation is the very beautiful Caslon Old Style No. 337. It was designed by William Caslon, an engraver, in the early eighteenth century. Its characteristic is that of simple, honest design and perfect craftsmanship.

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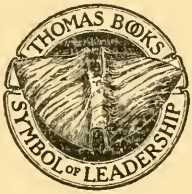

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