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中國古生代珊瑚化石

葛利普著

中華民國十一年九月

農商部地質調查所印行

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V. K. Ting and W. H. Wong

Palæozoic Corals of China

Part I. Tetraseptata

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Introduction, and Petraiidæ Streptelasmaidæ and Cyathaxonidæ.

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中國古生代之珊瑚化石

葛利普原著
孫雲鑄譯述

第一部　四射珊瑚

四射珊瑚 Tetraseptata 科之各種珊瑚、赫克氏 Hæckel 常稱之爲四珊瑚類 Tetracoralli、愛德瓦斯氏 Milne-Edwards 則謂之多放線類 Zoantharia Rugosa、法拉希氏又謂之翼珊瑚 Pterocoralli。余以爲此類珊瑚之特徵以具有四隔壁、故名之曰四射珊瑚。猶之六射珊瑚之隔壁爲數六、八射珊瑚之隔壁爲數八、無射珊瑚之隔壁常不顯露、或僅爲刺狀體也。

無射珊瑚 Aseptata 及四射珊瑚 Tetraseptata 兩科多屬古生代。始則由原始之無射珊瑚進化、繼即分爲兩類。六射珊瑚又由四射珊瑚進化而來、故六射珊瑚進化初期中、常顯有原始四射式階級 primitivet etraseptate stage。

構造概論

珊瑚 corallum 由珊瑚虫 polyp 分泌物質而成。或爲單體、或爲羣體、視珊瑚虫之數目而定。羣體珊瑚之個體、謂之珊瑚個體 corallites。由單獨珊瑚虫 polypite 分泌物質而成、常與附近之各個體相連接。珊瑚之爲單盃形者曰盃部 caliculum。

外壁 epitheca 以內之面積爲珊瑚體 thecarium。珊瑚體上部之盃形凹穴爲萼 calyx。珊瑚體內之各種構造極複雜、分述之如次。

四射珊瑚之體形學

外壁

自構造方面言之、四射珊瑚及無射珊瑚之緊要部分爲外壁、因珊瑚體悉爲外壁所包圍、而珊瑚體又包含其他各緊要部分故也。昔日每視珊瑚之隔壁 septa 爲重要部分、外壁不過爲內壁 theca 之後加物、此蓋由研究珊瑚者、多根據六射珊瑚之堅部 hard parts。（六射珊瑚之隔壁每與內壁相連）是以後生之內壁名爲眞壁、初發生之壁反爲外壁也。

既知四射珊瑚各個體之發育、則外壁爲珊瑚堅部之最要部分、已無疑義。珊瑚最初發生時、僅爲無隔壁之空盃、然大半常發見第一期之隔壁、其第二期隔壁漸次發生、隔壁發生愈早、則發育愈速。原生狀 primitive type 之珊瑚體常無隔壁、足證四射珊瑚爲無射珊瑚進化後之一科。

外壁初生、僅爲石灰質小塊、又稱珊瑚骨 sclerites、與幼珊瑚虫細胞相離、多數骨質結成底板 basal plate。珊瑚虫藉底板連接於他種物體上、此種物體或爲生物遺殼、或爲較古珊瑚之外壁、或爲海底之堅泥。珊瑚虫生長時、底板上之新石灰漸次增加、形亦增大。如底板由四周增加、則面積特別增大、外壁之生長線 growth-lines 爲石灰質次第增加之明證、且爲外壁之特別標記。設外壁上石灰圈 calcareous rings 增加率與珊瑚虫生長率相等、則成平盃狀。古生代之珊瑚之屬此者、如 Palæocyclus（第一二圖）Microcyclus, Baryphyllum, Combophyllum 及 Hadrophyllum 等。然古生代珊瑚石灰質之增加率、大半較速於珊瑚虫底部直徑之生長率。是以石灰圈恆由下而上、（非由內向外）遞次增加、層層相疊、婉如圓錐狀之盃部、普通珊瑚常有之。平盃狀之珊瑚、其底部亦有爲圓錐狀者、後因四周擴張、致成平盃狀、此即表明珊瑚四周增長速度以末期爲最大。

然大半珊瑚直徑之增大時期、初期尤勝於末期也。

珊瑚盃部之爲平盤狀、即珊瑚生長於硬物體上之結果。例如近代之Manicina屬珊瑚、生長於硬海底上者、其形狀率扁平、生長於軟海底者、每爲圓錐狀、此乃環境 environment 適合使然、或爲天然選擇 natural selection 之結果。如珊瑚有成平底之能力者、始能寄居於硬物體上、具圓錐形者、即易埋沒軟泥中。

珊瑚對於海底之適合理論 theory of adaptation 、或可用以解釋近代珊瑚、然古生代珊瑚每不適合、因平底狀之 Microcyclus 屬常與圓錐狀之 Stereolasma 屬同產一岩層中。且珊瑚之有盃部、乃其特別標記、非因適合而生。

盃部爲珊瑚之特別標記、且爲各種珊瑚分別之基礎。如擴張率 rate of expansion 速、則盃部多爲寬圓錐形。(見第三圖)擴張率小、則成長圓錐形。(見第四圖)珊瑚各屬各種之區別、似不可完全根據擴張率、亦必具有他種變化 variation 。大概珊瑚種類之變化、恒受環境之影響。如海水之成分、珊瑚虫之食物、皆足以影響珊瑚虫之生活、珊瑚虫生活既受影響、則珊瑚直徑之增加與石灰質之沈澱亦當不同。惟同產一地之珊瑚、其變化即爲生物之主要分別。考其發育情形、其譜系 genetic series 亦當不同也。

四射珊瑚之盃部、有時生長極有規則、有時至相當時期即止、則外壁之石灰圈、漸次由下上增、惟直徑不變、其結果成爲圓柱狀之盃部、(底部仍爲圓錐狀)如第五圖。圓柱體直徑之大小、視珊瑚擴張之遲速爲比例。擴張率速、則其所成之圓椎體低、圓柱體之直徑恒較圓錐體之直徑爲大。擴張率緩、直徑即變小、如第六圖。

四射珊瑚當經過圓柱生長時期 cylindrical growth 、其直徑漸縮小、故盃部之口甚小。(如第七圖)亦有

珊瑚虫驟然縮小、而盃部上部如蓋者。（即珊瑚之盃部極小）凡珊瑚直徑縮小、所以表明珊瑚身體收縮、亦即爲其衰老之一證。所以致此者、或因受病而身體損傷、或因境遇不適合而減小其體格。有時珊瑚虫收縮後、旋卽張開、呈互疊圓錐形。此類珊瑚收縮雖緩、然每次收縮必繼以擴張、故盃部極無規則之可言、（如第八圖）雖或不甚顯著、然視珊瑚外部之同心生長皺紋 concentric growth wrinkles 、固自有其例矣。

單體珊瑚多爲灣形、（第六圖）尤以具細長圓錐形者爲著。盃部之所以灣曲、實由于造成外壁石灰圈之厚度不均、灰質堆積最厚處爲凸邊 convex side 、凸邊每爲主隔壁 cardinal septum 所在處。間亦有在對隔壁 counter septum 或側隔壁 alar septa 兩處者。曲度方向之變更、恆在九十度以上、故盃部之平面常與珊瑚幼部之軸平行、如 Pinnatophyllum norini 是。

珊瑚生長方向之驟變、本非通例、然未變以前、其生長方向極有規則、後因珊瑚虫衰弱、故生長方向亦變、所生之新方向、常與其舊方向成垂直。（如第九圖）

珊瑚生長之情形

珊瑚初爲極細部分、曰原部 initial portion 。生長於他種物體上、或自由生長不與他種物體相連接。然具細長之原管 initial tube 、每以一端與他種物體相連接、其相連處爲組成外壁之物質、發育特甚、常成極無規則之底。蓋環境使然也。

同種珊瑚生長於流水中者、其底強、生長於靜水者、其底弱、因無他種物質加入故也。蓋珊瑚能造成堅固之底

者、始能生活於流水中、否則只在靜水中耳。

珊瑚盃部生長時、常於側旁發生根形苞 root-like proliferations（第一版第二十二三兩圖）漸由空管變爲堅固。當珊瑚生長時、新苞猶存在、至珊瑚末期、狀如外壁之底部擴張 basal extensions。根形苞爲珊瑚各譜系之特別標記。然各類珊瑚之相互關係、尙難由此斷定。蓋同屬各種珊瑚、有具根形苞者、亦有不然者。如 Amplexus 屬珊瑚中、僅 Amplexus spinosus（第一版第二十三圖）一種具有根形苞。有時損壞遺失、惟外壁面上顯有節瘤 node、以明其所存在者、如 Rhizophyllum 及 Omphima 兩屬是。結瘤之顯著與否、以發育之程度爲斷。

羣體珊瑚之外壁

羣體四射珊瑚中其母體 mother corallite 邊、常發生新芽 bud。設珊瑚爲疎鬆物質、則外壁之重要亦如單體珊瑚。然有時因珊瑚虫擴張常發芽苞、以連合各個體、使變爲堅固、後因珊瑚虫收縮、石灰物質仍繼續分泌、故芽苞常著其旁。（Eridophyllum）

羣體珊瑚生長頗密、則各個體因擁擠而變爲多角形 prismatic、其盃部邊上常因主要隔壁位置之更迭、以致外壁（兩層）變爲多曲形、如第十圖。

有時羣體珊瑚外壁全失、因隔壁生長速度驟增、致各個體之隔壁互相連絡、此種現象以上泥盃紀之 Phillipsastræa 屬爲最顯著。此屬乃從牆壁發育之一屬進化而來。不特此屬爲然、凡各譜系中之末期生物 end members 莫不皆然。羣體珊瑚生長過密、其外部各個體之外壁、常結合成圍牆 paritheca、以圍繞珊瑚全

體。

隔壁溝

珊瑚盃部之外壁、因厚薄不同、面上常有縱溝、縱溝內部爲隔壁、即每一隔壁面必對一縱溝、故名曰隔壁溝。單體珊瑚兩隔壁間之外壁、常向外突出、有時誤認爲外隔壁 costæ。外隔壁爲隔壁之向外延長部分、以六射珊瑚爲最顯著。（如第十一圖之b）四射珊瑚盃部外邊之縱溝、亦可稱之爲外隔壁溝 costal grooves。（如第十一圖之a）

隔壁之生成

四射珊瑚之隔壁、就其發生之次序、常得分爲第一次 primary 第二次 secondary 第三次 tertiary 等隔壁。珊瑚長成時、其第一次隔壁與第二次隔壁極相似、亦可總稱之爲第一次隔壁、第三次隔壁當爲第二次隔壁。

第一次隔壁包括主隔壁 cardinal septum 對隔壁 counter septum 及側隔壁 alar septa。第一次隔壁有時生長極速、故各隔壁同時發生。（如第十二圖）有時主隔壁及對隔壁最先發生、分盃部爲相等左右兩部。（如第十三圖）原初珊瑚隔壁初生、漸次長大、終即交於中心。惟發育特甚之珊瑚、其主對兩隔壁發生後即相交。側隔壁發見似分盃部爲四部、上兩部爲主部 cardinal quadrants、下兩部爲對部 counter quadrants。（如第十五圖）

古生代有數類珊瑚、其側隔壁發生地位與主隔壁及對隔壁之距離常相等、故各部亦相等。然大半側隔壁多

與主隔壁相近、故對部常較主部爲大。其第二次隔壁、亦先發現於對部、如第十六圖。雖亦有數類珊瑚之主部、因發育特甚、故較大、然第二次隔壁是否先在此主部發現、尙屬疑問。欲解決此問題、非研究此類珊瑚之幼小者不可。

第二次隔壁之第一對、常發見於對部、第二對則發見於側隔壁及第一對隔壁之間。質言之、即對部近側隔壁處爲發育最速部分、發育愈速、則此部繼續增大、新隔壁亦卽隨之發生、如第十七圖。此種新隔壁、常與側隔壁排成羽狀 pinnate、其發生之地位、次第增高、觀外部外隔壁溝 costal grooves、即可知其排列之情形矣、如第十九圖及第一版第二圖之a第十四圖之a。設對部發育特甚、則第三次隔壁之發現、常在第二次隔壁未完全發育以前。（第十八圖）近對部兩邊所發現之隔壁、每爲第二次隔壁、如 Cyathaxonia 屬珊瑚之第二次隔壁、常與第三次隔壁輪流發生。卽每一對第三次隔壁發生、必在相對之第二次隔壁之後、此種隔壁在對邊者 counter side 每發生於對部、在側邊者、發生於主部。此種現象、將於此屬各論中詳言之。

主部之近主隔壁處、爲隔壁最先發生處、發育頗速、新隔壁常繼續加入。（如第十七十八兩圖）惟近側隔壁處則反是、生長極緩、其第二次隔壁幾與側隔壁平行、第三次隔壁間亦發生、新隔壁之位置繼續增高、且與主隔壁排成羽狀。此種現象、各種原初珊瑚之隔壁溝表明最顯。（如第二十圖及第一版第十五圖之a）

珊瑚有四處、最爲發育、卽對邊近側隔壁及主隔壁之兩旁、新隔壁常與舊隔壁相交、有時一象限 quadrant 之各隔壁、常如是相交、成爲四分式隔壁組 quadripartite septal grouping、如第二十一圖。所生之裂口爲生長最發育之處、且有無第三次隔壁及橫板 dissepiments 挿入、名曰側假內溝 ala pseudo-fossulæ。此種現象四

射珊瑚之幼者多有之、其地位常在近側隔壁處之對邊、所以表明各個體進化之階級。若長成之珊瑚、仍具此現象、則爲退化矣。如第一版第十四圖之b。

主假內溝 cardinal pseudo-fossula 亦所以表明進化中之各階級。若長成 adult 之珊瑚仍具此溝、或其側近第二次隔壁仍爲羽狀、皆所以證明生物之退化。如 Aulacophyllum 及 Pinnatophyllum 等屬皆是。主面積爲發育最盛之處、兩主裂口 cardinal gaps 常因主隔壁之損壞、合一而爲眞內溝 true fossula。

內溝之意義

內溝由於主隔壁毀壞而成。如主隔壁發生於珊瑚最大灣曲處側近 side of greatest curvature、則關生物個體之病理學、若發生於凹邊、即爲衰老之明證。大抵長成之珊瑚、其主隔壁爲第一次隔壁中最先發生者。即不然、亦可謂生物發育初期中一緊要構造也。多數珊瑚、由幼而老、其主隔壁皆甚發育、然亦有一種珊瑚、當幼稚時、其主隔壁非常發達、至末期、即衰萎、是以內溝之發生時期、僅限於各種生物（或數種生物之變種）衰老時期。質言之、內溝爲珊瑚緊要構造之一、常發生於生物末期。然亦有生物譜系中之初期珊瑚、多無內溝、惟末期之衰老者、乃大顯著。如 Streptelasmaidæ 屬珊瑚之內溝、在泥盆紀以前、率未之見、至泥盆紀時、此屬之最發育者、始具內溝。又如 Zaphrentidæ 屬珊瑚、在幼稚時、其內溝已發生。然則內溝爲珊瑚譜系各屬末期之一緊要構造已無疑義。又如大圓柱狀珊瑚之具床板者、常因之而成漏斗狀內溝 siphonofossula、屬於此者爲 Siphonophrentis 及 Siphonophyllia 兩類珊瑚。此類特別組織常與珊瑚虫軟體之構造極有關係、不可不察焉。

內溝爲珊瑚之特別標記、既如上述。茲就生物譜系論之、內溝有發生早者、有發生遲者。大抵具有內溝之各種珊瑚、較無內溝者爲進化、而內溝發生較早之各種珊瑚、較發生遲者亦爲進化。又如同屬之兩種珊瑚、其一已至長成時期、內溝尙未發達、其一發育頗甚、且後者之地質年代較前者爲古、前類珊瑚卽不當與後者同屬一系、而別爲退化之一分支 retarded lateral branch。又如有兩種珊瑚、其一內溝在生物長成時始發達、其一在幼年已完全發達、至長成時常發生漏斗狀內溝、此兩種亦不可歸爲同屬。例如 Canimia 屬珊瑚、至長成時內溝始發現、而 Siphonophyllia 一屬、先經過 Canimia 階級、至長成時、常發生漏斗狀內溝。Siphonophyllia 屬之幼者、易誤認爲 Canimia、若能識別其幼椎之性質、卽易識別矣。各類珊瑚之內溝、以 Zaphrentis 屬爲最發達。吾人應知者、內溝乃表明生物進化之階級、無與於各屬相互之關係也。

隔壁之厚度

四射珊瑚之隔壁、常因石灰質 stereoplasm 之加入而益厚、其形如楔、中心最薄、近邊漸厚、至各隔壁相接爲止。有時僅一對隔壁加厚、餘均仍舊、屬此者爲 Pinnatophyllum norini 一種、其主部隔壁特別發育。此或由珊瑚受侵蝕時、惟主部保存較爲完全。有時各隔壁爲石灰質塡充、愈形堅固。有時石灰質之厚度、僅限於一部分、如 Pinnatophyllum (Hotorocaninia) tholusitabulatum (Yabe and Hayasaka) 是。此種隔壁之最厚處、常近四周、近中心處則愈薄。此種化石之外邊、在未埋沒以前、常有侵蝕痕跡、不若內部之堅固。

隔壁最厚處、亦有時在近中心處、形如內牆 inner wall、惟隔壁仍向內伸入、不若內牆之有規則、此種組織謂之灰質牆 stereotheca。以中國所產之 Tachylasma 屬珊瑚（共二種）爲最著。此種原初珊瑚之側隔壁及對

部第二次隔壁之一對、常特別加厚、爲其特徵。（第五十圖及第一版第二圖之b第三圖之a b第四圖第十三圖之b）

最可注意者、隔壁之厚度常限于最老部分、（卽珊瑚底部）不顯露于蓦上、然最厚之隔壁、亦常發見。幼珊瑚虫之外層、常爲摺疊狀、故此處石灰細胞、非常活潑。隔壁分內外兩層、皆于中心相交、隔壁增長愈大、外部石灰質之加入亦愈多、因之內外層亦極顯明。有時珊瑚外層變爲矽質、其內層仍爲灰質、故易溶解。隔壁之外端常與外隔壁溝相對、外隔溝中間爲外壁、常向外突起、外壁有時因骨質加入而益厚、且與隔壁兩邊之各骨質層 sclerenchyma 相連絡、否則側邊各層、仍分開爲橫葉 dissepiments。（如第二十二圖）

隔壁長度之變遷

隔壁生長愈速、其長度愈增、有時因擁擠而灣曲。如擁擠過甚、中心成柱狀物體、名爲灰質中柱 streptocolumella。此以 Clisiophyllum 屬爲最顯著、Cyathophylloids 次之、所以表明隔壁發育之程度也。

反之隔壁極短、無論老幼、悉不于中心相交。有時原初珊瑚之老者、近中心處常爲床板塡充、隔壁長至中心卽止、且不相交、此爲隔壁末端發育停滯之證。此種現象以 Amplexus 屬珊瑚爲最著。他類亦有之、但不明顯。如 Streptelasmaidæ 科中之各珊瑚、在泥盆紀卽如此、但極盛時期爲下石炭紀 Dinantian、如 Amplexus 屬珊瑚是也。他如 Zaphrentidæ 科則有 Siphonophrentis（中泥盆紀）Caninia 及 Siphonophyllia（下石炭紀）等屬、Cyathophyllidæ 科則有 Campophyllum 等屬、皆具此種性質。此乃表明生物發育之程序。而各屬之具此性質者、可謂爲發育之平衡 parallelism in development。然與各屬相互之關係無涉。

泥盆紀之 Mesophyllum 屬、其盃部中心常爲泡沫組織 cystose structure。有時盃部四周之隔壁、極不顯明、且爲泡沫狀、然其幼者、隔壁常達盃部之四周。(見珊瑚下部之橫斷面)如單體珊瑚之 Endophyllum、羣體珊瑚之 Spongophyllum 皆是。他如石炭紀之 Lithostrotionella 及 Lonsdaleia 亦有此種性質。蓋此屬生物、係由隔壁發育之各屬進化而來也。

脊板

脊板 carinae 爲隔壁兩旁之板片、常與隔壁相連。其位置或直立或斜置、(對於盃之平面而言)自橫斷面觀之、此板宛如隔壁中間之橫壁 cross bar、爲泥盆紀 Heliophyllum 屬化石之特徵。(如第二十三圖)然其幼者、常不顯露。脊板之多少、常與此屬珊瑚生成之年代爲比例。脊板發育緩則發現遲、即長成之珊瑚、其脊板亦不多。反之發育速、則發現早、長成之珊瑚、其脊板亦多。各類生物進化速度之比較、皆可於長成珊瑚脊板之多少定之。脊板與前所論之內溝均無與于各屬相互之關係、僅足以表明各屬進化之階級而已。凡具脊板者、不必爲 Heliophyllum、即 Zaphrentis (原屬 genotype)亦有之。

脊板有時發育不著、僅長成之珊瑚有之。如泥盆紀 Pinnatophyllum scyphus 種之 carinata 一族是。有時有某屬數種中一種、具此性質、如泥盆紀之 Zaprentis cornicula 是。有時各種皆然、而爲某屬之特別標記者、如 Heliophyllum 屬。(Cyathophyllum 變屬)

脊板之位置、亦有平鋪者。常發生於隔壁之兩旁、且不對稱、縱斷面及斜斷面均足以表明此種現象。如 Lophoplasma 及 Lophocarinophyllum 兩屬、見第五十四至六十三各圖及第一版第六至第十一各圖。有時脊板外

邊向上灣曲、自斜斷面觀之、極似灣鈎。(第一版第九圖之d)橫斷面有時截脊板之上部、脊板則爲隔壁之附壁、婉如雙隔壁焉。(如第一版第五圖之b)

橫板及泡沫板

橫板 dissepiments 爲隔壁間之平板、斜置底部、上部略凹。骨質物常從中間插入且與隔壁相連結、如第二十二圖。(見第十六頁)近中心處之橫板、常輳合成爲床板或爲床板面積 tabulate area。有時此板互相連接成爲骨質壁 sclerotheca、極似內牆。然究與內牆有別、蓋隔壁常越之而穿入中心故也。

泡沫板 cystosepiments 亦爲隔壁間之板、爲泡沫物質所組成。上部凸起、爲動物軟體收縮及灰質沈澱之一證。泡沫板發育完全、與橫板極易分別。惟有時漸變爲橫板、無判然之界限。

床板

床板 tabulæ 爲珊瑚中心之平面板、四周之床板常變爲橫板。有時床板僅發生於內壁以內、珊瑚之四周、悉爲泡沫組織。間亦有床板完全經過盃部者。床板所以表明珊瑚盃部及隔壁之進化。珊瑚之幼者、常無床板、惟長成者有之。又原初珊瑚亦無床板、即其長成者、床板亦不多。例如 Zaphrentis 之標式化石 typical form、常無床板、然此屬之長成者、亦常有一床板。發達較完全之 Heterophrentis 屬、亦常有之、初發見之床板、相隔頗遠、後發生者則較密耳。他如發達最完全之 Canina 及古生代後期各屬珊瑚、其床板極多、層層相疊。可知愈發育者則其床板愈多。床板發生愈速、則愈不完全、中心僅有一部分與已成之床板相結合。有因中心突起爲旅棚狀者、如 Acrophyllum 屬是。因灣曲爲螺狀者、如 Lonsdaleia 屬是。有中心突起爲柱狀者、如 Lithostro-

tion 屬是。

泡沫組織

泡沫組織 cystose structure 珊瑚各屬均有之。有僅限於盃部一部分者、有完全以此填充者。當盃部完全爲此物質充滿時、其隔壁常顯於上面、卽知泡沫 cysts 實先隔壁而發生、如 Microplasma 是。有時發生於隔壁之間、後漸全變爲此種組織、如 Actinocystis 是。有發生於外部 outer zone 者、如 Endophyllum 及 Lonsdaleia 等是。亦有發生於內部 inner zone 者、如 Mesophyllum 是。泡沫爲珊瑚虫分泌之物質、上部常隆起、爲當日生物軟部收縮之一證、其組織多且細、間亦有較粗者。有時外部粗泡沫部與外壁同受侵蝕、完全毀壞、故珊瑚外部、形極粗糙、如 Blothrophyllum 是。

內牆

內牆 inner wall 因其組織之不同、可分四類、茲先就論每類組織之大概、再述分類之結果、

（一） 安特生君 G. E. Andersson 曾研究珊瑚薄片、發明 Crepidophyllum 及 Eridophyllum 兩屬眞內牆之由來、其隔壁常排列成爲四分式隔壁組 quadripartite、至長成時、後生隔壁之末端 inner ends 常灣曲成直角、以與第一次隔壁相連、如二十四圖。對部各隔壁、其末端常從兩邊向對隔壁灣曲、且互相連接而成內牆。主部之各隔壁、則向兩邊之側隔壁灣曲、亦連接成內牆。故內牆共有三裂口 gaps。其在兩邊者爲側假內溝 alar pseudo-fossula、其在主部者爲主內溝 cardinal fossula。兩邊之裂口、常有橫板經過其上。Crepidophyllum 屬之主部裂口常開、故內牆開口處、亦在主部、形如馬蹄。Eridophyllum 屬則不然、其幼時之內牆、雖與 Crepi-

dophyllum 相同、及至長成、內牆益發育、其裂口因以閉塞、如第二十六圖。凡此種長成之珊瑚、其第一次及第二次隔壁常向內部四射、且與內牆相連、然決不越過。其內牆之內部、常爲床板所填充。第三次隔壁多不與內牆相接。總之長成之珊瑚、其完全內牆常爲管狀、隔壁不能穿入。且此種眞內牆完全爲隔壁所造成、故可稱之爲葉壁 phyllotheca。

(二) 內牆亦有以橫板 dissepiments 組成者。其至中心及邊爲等距離。但此非眞內牆、因其隔壁（第一次及第二次）每穿入而達中心、如第二十七圖。此種假內牆謂之骨質壁 sclerotheca。其與隔壁之相互關係、極似六射珊瑚。惟六射珊瑚之隔壁常向外伸出、（其伸出之部分謂之外隔壁 costæ）爲其異耳。總之此種假內牆爲骨質 sclerites 所組成、完全與隔壁無關、如 Diplophyllum Lithostrotion 及 Acervularia 等屬有之。

(三) 珊瑚近中心處之隔壁、厚度驟增、且互相連絡、如此者亦謂之假內牆、如第二十八圖。此種假內牆與葉壁及橫板壁極易分別、因此爲石灰質 stereoplasm 所成、故亦謂之灰質壁 stereotheca。歐美泥盆紀 Pinnatophyllum 屬之各種、歐洲上泥盆紀之 Phillipsastræa 屬皆有之、尤以 Pachyphyllum 屬爲最著。此種內牆之地位與珊瑚盃形極有關係、最普通者其蕚 calyx 之四邊極平、內部恆凹。即具橫板壁之 Acervularia 屬亦有此現象。

(四) 第四類之內牆、與前三類迥異。其具此者泥盆紀則有 Depasophyllum 屬、下石炭紀 Dinantian 則有 Diphyphyllum concinnum 種。此種內牆爲床板所組成、其四邊常向下灣曲、婉如盒蓋、且層層相疊、如第二十九及第三十兩圖、極與葉壁 phyllotheca 相似、惟常爲葉朵狀 scalloped 形如海扇、其隔壁從未穿過內牆、

(間亦有達床板之上面者)爲其特徵。

此種內牆、亦可稱之爲盃壁、cyathotheca 因如倒置各盃相疊而成。設珊瑚外隔壁帶 outer septal zone 損壞、則成有槽之圓柱體、如第三十圖。

四射珊瑚之內牆、至少可分爲四類、

一　眞內牆或葉壁、爲隔壁所組成、其隔壁常灣曲成直角、且互相連接。具此者爲 Crepidophyllum 及 Eridophyllum 兩屬。

二　橫板壁或骨質壁、爲一排或數排之橫板所組成。具此者爲 Acervularia、Diplophyllum、及 Lithostrotion 等屬。

三　灰質壁由動物分泌石灰質而成。此處隔壁特別發育。具此者爲 Prismatophyllum、Phillipsastræa 及 Pachyphyllum 等屬。

四　床板內牆或盃壁、爲床板所組成。其床板常向下灣曲、如各盃倒置於床板上。具此者爲 Depasophyllum 及 Diphyphyllum 兩屬。

上列四類內牆、除第一類爲眞內牆 holendotheca 外、餘均爲假內牆 pseudendotheca。第一類之隔壁常不通過內牆、第二及第三兩類之隔壁常通過內牆、第四類之隔壁亦恆不通過、間亦有達床板上面者。

中柱及假中柱

眞中柱 true columella 爲珊瑚中心突起之部分。形如尖柱、自盃部 thecarium 之底直達萼口、惟六射珊瑚有

之、如始新統之 Turbinolia 等是。其構造簡單、間有複雜者。或爲堅固物質、或爲疎鬆物質、其爲珊瑚虫最初分泌之物質則一也。四射珊瑚之中柱、其結構非原始的、實乃次生的 secondary。質言之、即此種中柱、僅長成之珊瑚有之。其各隔壁相交處厚度特增、故成中柱。有主隔壁與對隔壁相交而成者、如 Cyathaxonia 是。（如第三十一圖）有各種隔壁相交而成者、如 Lithostrotion 是。（如第三十二圖）有因對隔壁末端厚度特別增加而成者、如下石炭紀之 Lophophyllum 是。（如第三十三圖及第一版第十五圖之b）有因對隔壁之末端 inner ends 分開而成者、如 Lophophyllium proliferum 一種是。（如第三十四圖）四射珊瑚之各類中柱、其形狀極似圓柱、乃從蕚底發生者也。

假中柱 pseudocolumella 亦可分爲數類、

中柱由近中心處之各隔壁末端互紐而成者、謂之互紐中柱 streptocolumella。如 Streptelasma 及 Clisiophyllum 等屬是。亦有長成之珊瑚、其中心因骨質或灰質之沈澱而成者。前者物質疎鬆、謂之骨質中柱 sclero-columella。如 Enterolasma（如三十五圖）屬之。後者物質堅固、謂之灰質中柱 stereo-columella。如 Stereolasma 屬（第三十六圖）及 Lopholasma（如第五十二圖）等是。有時中柱亦爲床板所組成、形如圓錐、謂之頂生中柱 Acrocolumella。如 Acrophyllum 是。亦有中軸特別發育者、如 Lithostrotion (typical) 屬是。

有時珊瑚之盃、其突起部分完全以泡沫組成者、謂之泡沫中柱 cystocolumella、如 Heliophyllum 數種及其他各屬等是。最複雜之中柱、乃集合上列數種組織而成、如 Lonsdaleia 及其他各屬等是。世之鑒定化石者、欲診斷其爲何屬、則中柱之分類似不可不察也。

羣體珊瑚之生成

四射珊瑚中之羣體珊瑚、其各個體係從母體發生、此種產生法謂之分芽法 budding。芽苞發生太多、偕母體繼續生長、故羣體珊瑚之個體 corallites 亦多、且相連接。蓋珊瑚生長密、珊瑚虫常爲多角形、故珊瑚之橫切面、亦爲多角形。各個體之牆壁或連續或分離、視其發生之情形而異。設僅有一芽從母體發生、且與母體同時生長。此種個體之組織、極疎鬆、且不相連接、其切面每爲圓形。

分裂法 division 六射珊瑚最爲常見、四射珊瑚則極稀。兩盃中間之分芽法 intercalicinal budding 亦如是、其新芽係從珊瑚個體相連處 extrathecal portion 發生、亦即珊瑚虫連續之處。四射珊瑚之新個體、常由卵發生、然與母體毫無關係。

個體進化論或發生學

珊瑚虫之發生學 Ontogeny、雖與環境有關、然實根據於生物之遺傳性 heredity。珊瑚堅部之有各種體形階級 morphic stages、所以表明珊瑚虫進化之次序、欲研究此種進化程序、可先研究珊瑚之各種切面、以珊瑚幼時之性質爲最詳故也。近時依此方法研究者、僅有數類。大半各屬之關係及各種各屬之性質、仍根據於長成珊瑚之性質、實非正當方法。設期學有進步、非將每屬珊瑚最要各種珊瑚之切面、詳細觀察不可也。

加速度與遲緩度

瑚個體生長時珊、其一部生長之遲速率或異。大抵某種珊瑚之各個體有一定產地、故其生長率常不變。有時某處所產之某種珊瑚、生長極速、雖未至成年時期、其各種性質、已與長成者無異、此個體之進化、謂之速進加

化、故每成爲加速變種 Mutations。若發育極緩之個體、則謂之遲緩進化。此種生物雖至長成時期、仍具幼年性質、亦常成爲遲緩變種。加速度 acceleration 與遲緩度 retardation 有時影響于生物全個體、有時僅及於一部分。(即不等加速度及遲緩度)蓋一種珊瑚常有某部發達頗速而他部分則遲緩者。此種情形易發生一種新譜系。如某種珊瑚、其內溝已發達、而其隔壁仍爲第一次四射式階級、甚至脊板亦發生於退化隔壁之上、屬此者爲 Pinnatophyllum scyphus 及 P. scyphus var carinata。他如同一祖先之珊瑚、其隔壁發達已由四射式 tetrameral 變爲輻射式 radial、但無內溝及脊板、如 Cyathophyllum 屬是。亦有脊板在幼時已發達、其隔壁亦爲輻射式、但內溝多不發育、(亦有例外者)如 Heliophyllum 屬是。故欲研究生物個體、不可不知其進化之程序、而其進化之程序、非研究形態學不爲功。

生物進化之加速與遲緩、或受環境之影響、或可歸於遺傳性之解釋。

羣體珊瑚中進化之加速度及遲緩度

羣體珊瑚爲各個體結合而成、其中發育特著者有之、生長遲緩者亦有之、即如 Phillipsastræa 珊瑚、其個體中之牆已損壞、隔壁常向外伸出、而與隣近之隔壁相連接。然亦有珊珊各個體之牆、仍完全保存者。是則此羣體珊瑚中已具有兩種性質。

羣體珊瑚常保存其祖先性質、與 Phillipsastræa 屬極相似、(牆甚顯明)有數個因體進化而隔壁伸出、同時珊瑚之牆亦因擁擠而損壞。又如 Lithostrotion 珊瑚之個體、其中柱應非常發達、然因退化而顯祖先之 cyathophylloid 階級者、如 L. kaipingense 一種。此類羣體珊瑚顯似有兩屬珊瑚性質、然尋常鑒定化石、僅用一

種名、而此種之性質、必爲羣體中各個體所公有。羣體珊瑚發生之加速度與遲緩度、既已了解、則各種複雜珊瑚之解釋皆可迎刃而解矣。

然發育之所以遲緩者、亦有因生物一部分遇損傷而然者、(屬病理學)全與羣體無關。例如羣體之芽因壓迫而捐傷、餘皆甚發育、且爲圓柱狀。圓柱狀爲羣體中母個體 parent corallite 之特別標記。如生長過密、則珊瑚各個體常爲多角形、屬此者爲 Lithostrotion, Prismatophyllum 等屬。

生物常因環境之關係而受損傷、則發育亦遲緩。然有一部分因之而反發育者、此蓋絕無而僅有者矣。

各論中之原理、僅指保存完全之標本而言。然亦有數類化石之個體、顯有發育之階級、雖可用以解釋、然最後之決定、非深明每種之發生學不可也。

各種珊瑚之圖、其位置皆固定、對隔壁在上、主隔壁在下、上兩部爲左右兩對部、下兩部爲左右兩主部。

珊瑚各論　科屬種

第一科　Petraiidæ de Koninck（經葛利普修正）

單體珊瑚構造之最簡單者、每具有外壁及脊狀之短隔壁。即此科之最發育者、其隔壁亦鮮達中心。故此類長成珊瑚之現象、即他類珊瑚幼時之現象。如 Petraia 初期數種珊瑚 early species 常爲他種四射珊瑚之祖先。

此科瑚瑚分爲下列兩屬。

一　Petraia Münster 奧陶紀至石炭紀

二　Polycoelia King 二疊紀

古生代末期之各種瑚瑚、多具有各種原始性質。上列兩屬、中國尙未發見。

第二科　Streptelasmaidæ Grabau（經修正）

珊瑚種類不一、常由低級漸至高級。始則多無隔壁、繼則雖有而不相交、吾人謂之 Petraia 階級、終則各隔壁互交於中心。大抵低級珊瑚、其隔壁每爲四分式排列 quadripartite 假內溝 pseudofossulæ 亦因之而生。（第十三頁插圖第二十一）最高級珊瑚則不然、其隔壁每爲放射狀、常因延長而扭交於中心。脊板 carinæ 普通珊瑚常有之。內溝僅階級最高之珊瑚 specialized types 有之。假中柱由石灰質組成者、如 Lopholasma 及 Stereolasma 等是。假中柱或爲粗棒狀者、如 Lophophyllum 等是。無床板、惟最高級之 Amplexus 屬有之。橫板 dissepiments 極少、有時不見。對部第二隔壁之數常較主部爲多。此科各屬詳載英文論文中。（第二五頁）

中國各屬及各種珊瑚

Stereolasma Simpson

此屬長成之珊瑚、其隔壁成放射狀、眞內溝亦頗發育、橫板極普通、但無床板與脊板。灰質中柱 Stereocolumella最發育、但不達蓌部 calyx。發育情形可參觀此種珊瑚放大斷面圖(第三十二頁插圖第三十七至四十七)

Stereolasma rectum (Hall)

中國僅發見一枚、產雲南泥盆紀岩層中。第一版第一圖之a表明此種化石之形狀及性質、第一圖之b爲其二倍放大斷面圖。

Tachylasma Grabau (新屬)

此屬與前屬迥異、具有側隔壁及對部最初兩片第二隔壁。此種隔壁下部極厚、上部常突出於蓌口、爲此屬發育特速之明証。tachygenetic 意即加速、故此屬定名爲 Tachylasma、且爲中國之特產。

Tachylasma cha Grabau (新種)

此種形似 Stereolasma rectum、隔壁厚度極有規則。形如乂字、種名曰 cha、即取此意。橫板極少。中國石炭紀岩層中產之。(第一版第二圖之a b及插圖第五十)

Tachylasma elongata Grabau (新種)

形細長。惟此種長成珊瑚 adult 之隔壁、不似前一種之厚。曾發見於江西豐城石炭紀岩層中。(第一版第十三圖之a b及c)

Tachylasma aster Grabau （新種）

形細長、隔壁最厚者有四片。迨長成時、其每一主部之兩片隔壁每一對部之四片隔壁（第三圖）及一對隔壁常繼續增厚、（對部隔壁總數爲十一）交於中心而成星形。（種名即取此意）珊瑚幼部斷面 younger sections（第三圖之 a 及第四圖）隔壁增厚者極少。此種最新發生之隔壁亦如 T. cha 一種、蓋由 T. cha 進化而來者。此種最初階級 earliest stage 之性質與 Streptelasma 相似、見插圖第五十一。（第四十一頁）浙江長興煤系石炭岩中產之、似屬二疊紀。（第一版第三圖之 a b 及第四圖）

Heterelasma Grabau （新屬）

此屬以具有四假內溝、爲其特徵。對隔壁頗短成對內溝。已發見者僅 Heterelasma edwardsianum （de Koninck）一種。第一版第十四圖之 a 爲其放大形。第十四圖之 b 爲其蓎之特別放大形。產於歐洲石炭紀岩層中、中國從未發見。（第一版第十四圖之 a 及 b）

Lopholasma Simpson

此屬與前列各屬迥異、具有灰質中柱 Stereocolumella、但未達蓎部、是其特徵。又隔壁兩旁具有平脊板。（亦有向上捲曲者）脊板方向視斷面方向而異。其向上捲曲之部有似補隔壁 supplementary septa 者、（正橫斷面）有似隔壁之分支者、（稍斜斷面）有成鈎形者。（斜斷面）插圖第五十二及第五十三爲一種泥盆紀此屬化石之縱斷面。泥盆石炭兩紀均有之。

Lopholasma carbonaria Grabau （新種）

形細長稍灣曲。此種珊瑚之各橫斷面、所以表明隔壁發育之次序、見第七圖d至第十一圖d各圖。又插圖第五十四至第五十六爲其中三圖之放大形。第五十四圖(下面)及第五十六圖與第五十五圖(上面)相反。長成之珊瑚、每發生內溝、無中柱。(插圖第五十六及第一版第十二圖)

此種爲山西太原系之普通化石、每發見於山西太原縣關底溝石灰岩中、河南山東亦產之、均屬下石炭紀上部。(第一版第五圖之a b第七圖之d至第十一圖之d第十二圖及插圖第五十四至第五十六)

Lophophyllum E and H 及 Lophocarinophyllum Grabau 新屬

形小而細長、假中柱發育特甚、由對隔壁之內端變厚而成。Lophophyllum 屬之主要珊瑚、當初期時其中柱每與對隔壁相離。他屬之中柱則反是。

Lophocarinophyllum 與 Lophophyllum 之異點、前者具有平脊板、(板邊每向上捲曲)恰如 Lopholasma。插圖第六十五及五十二之比較、即所以表明 Lophocarinophyllum 屬之幼者與 Lopholasma 極相同。然此屬之老者、每發生假中柱且極明顯。其分別自易明矣。

Lophophyllum proliferum (Mc Chesney)

此爲北美普通化石之一種、亦產於中國江西樂平二疊石炭紀岩層中。曾經克綏爾氏 Kayser 研究。(參觀李希霍雰中國譚第四部第一百九十四頁及第二十九版第七至第十各圖)中國他處尚未有發見者。

Lophophyllum pendulum Grabau (新種)

此種之特徵、在假中柱與細長對隔壁相結處特別漲大。自上面觀之、婉如古式鐘之擺錘、故種名曰擺 pendu-

lum。隔壁有數脊板、橫板極少。產於河南石炭紀岩層中、或爲太原系之化石。然山西山東之太原系、甚少發見、是以產地終未能確定。又浙江產此種化石一枚、屬二疊石炭紀、（第一版第十五圖之a b第十六之a b第十七圖之a b及插圖第五十七）

Lophocarinophyllum acanthiseptum Grabau（新種）

形細長且灣曲。假中柱非常發育、突出於隔壁之上。隔壁上具有平脊板。（板邊每向上捲曲）此種現象可參觀各種斷面圖、如插圖第六十一至六十三。（第六十二圖與第六十四圖相反）又第六十五縱斷面與 Lopholasma（插圖第五十二及五十三）外形極相似。此種初期珊瑚及斷面與 Lopholasma carbonaria 尤不易分別。若具有假中柱、則不難分別矣。山東山西太原系岩層中均產之。（第一版第六圖a c第七圖a c第八圖a c e第九圖a c e f第十圖c第十一圖c第十八圖至第二十圖及插圖第五十八圖至第六十五）

Arachnolasma Grabau（新屬）

此屬比前列各屬珊瑚尤大、極似 Streptolasma 屬之大者。隔壁及橫板皆極多。假中柱常受壓迫、形如 Lophophyllum。惟其四周爲許多大泡沫 cysts 圍繞、是以珊瑚斷面、婉如蜘蛛之網、屬名曰 Arachnolasma、意即此。

Arachnolasma sinense (Yabe and Hayasaka)

已發見者、僅此一種。產貴州威寧縣下石炭紀岩層中。第六十六圖爲此種斷面圖。（放大一倍半）

（1920 Lophophyllum sinense Y and H 見支那地學調查第六版第二圖a至g）

Amplexus Sowerby

此屬主要珊瑚之幼者形似 Streptelasma 屬。至長成時、床板發育頗盛。隔壁每不達中心。盃部中央最平處爲上部床板組成。產四川志留紀岩層中。林德斯傳氏 Lindström 曾研究一種羣體珊瑚曰 Amplexus viduus、因立此新屬名 Synamplexus 也。

下述兩種列入此屬似頗可疑。

Amplexus (?) distans Lindström

直圓錐形、自下而上、形狀漸次增大。隔壁尖削甚速、惟近邊處稍灣曲。灰質圓周圈 peripheral ring of stereoplasma 頗窄。隔壁具刺狀物體、橫板顯明。床板極薄、每二十二公糎必有五層。四川東北志留紀岩層中產之。(李希霍雯氏中國譚第四卷第六十三頁及第六版第一圖至第五圖)

Amplexus (?) appendiculatus Lindström

此種具有根形外壁苞 proliferations。隔壁較前種爲多、且細長、似達中心。床板較 A. distans 尤複雜。產地與前種同。(見李希霍雯中國譚第四卷第六十三頁及第六版第七八兩圖)

Amplexus spinosus de Kon var sinensis Grabau (新族)

形小略灣曲。此族初期 early stage 與原初 Streptelasma 屬珊瑚相似、但長成時每發生床板、近中心處無隔壁。有橫板、隔壁極少。面上有根形苞。原種產歐洲下石炭紀岩層中。惟此屬形狀極小、盃部擴張極速、中央無隔壁之面積亦極小、長十七公厘之珊瑚、其萼之直經每爲十一公厘、皆此族與原種之異點。江蘇句容棲霞山石灰岩中產之、屬下石炭紀 Dinantian。(第一版第二十二圖之 a 及 b 及二十三圖)

Metriophyllum E and H

單體、形如圓錐。隔壁分爲四組、其主要隔壁常在中心成一十字。橫板易誤認爲床板。

Metriophyllum (?) poshiense Mansuy

珊瑚形如圓筒、具有三十六隔壁、皆不等長。最主要之四片、隔壁常達中心、其位置亦無一定。第二次隔壁較短、第三次隔壁尤短。此種珊瑚與歐洲所產者極不相同、或爲異屬化石。載普拉 Deprat 及滿蘇 Mansuy 曾發見於雲南中泥盆紀岩中。(見雲南東部古生物誌 Paléontologie du Yunnan Oriental 第四十七頁及第七版第八圖 a 至 d)

第三科 Cyathaxoniæ Edwards and Haime (經葛利普修正)

此科現在僅有 Cyathaxonia 一屬、形似 Lophophyllum 珊瑚。惟其中柱由主要隔壁組成、以相交處爲極厚、是其特徵。(見插圖第三十一)此種發育之情形、可參觀各斷面圖 successive sections。(插圖第六十七至七十四)對部第二次隔壁第一對之發見每在第一次隔壁完全發見以前、足證此屬發育速度較 Lophophyllum 爲尤大。(第六十八圖)是以主要隔壁最初發見多至六片。(第七十圖)其他各隔壁亦次第發生。同時第三次隔壁 t 一對、亦發見於對隔壁之旁。(ct 第七十一圖)始則此種隔壁多與老隔壁相接、繼則其內端因生長線稍轉位置、遂交於中心。發生之次序、雖與 Streptelasmaidæ 相同、然第三次隔壁發育速度極大。如每對第三次隔壁發生、必在一相當第二次隔壁之後。此與第二次隔壁已近完全發育後第三次隔壁始繼續發生者不同。

第三次隔壁發生次序、與他屬瑚珊相同。在對邊者每發生於對部、在側邊者每發生於主部。對部第二次隔壁之數每較主部多一、是對部實較主部爲發育。圖中 t_1 t_2 等表明第三次隔壁、1. 2 等數表明發生次序。 Cyathaxonia 屬爲歐洲下石炭紀 Dinantian 化石、中國尙未發見。

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PALÆOZOIC CORALS OF CHINA.

BY

A. W. Grabau

PART I. TETRASEPTATA.

INTRODUCTION

The corals here included in the order TETRASEPTATA, have been known by various ordinal names, among which that of *Tetracorallia* applied by Hæckel, is most frequently used. Other designations are *Zoantharia Rugosa* applied by Milne-Edwards, and *Pterocorallia* used by Frech. I have given the name *Tetraseptata** to this group in order to emphasize the tetrameral character of the septal arrangement which is fundamental in this order, and because it harmonizes with the ordinal names *Hexaseptata* applicable to those corals in which the fundamental arrangement of the septa is on the plan of six, *Octoseptata* where the number of mesenteries, and septa, when developed, is eight, and *Aseptata* where the septa are either absent, or rudimentary and in the form of spines. The Aseptata and Tetraseptata include primarily Palæozoic corals, and they appear to represent two distinct evolutional branches, joined together by the earliest and simplest type of the aseptate group which thus is to be regarded as the more primitive of the two. The *Hexaseptata* on the other hand are derivatives of *Tetraseptata*, as is clearly shown by the primitive tetraseptate stage through which many of them pass in their earliest periods of ontogenetic development.

GENERAL TERMS.

The entire coral mass, whether simple (formed by one polyp only) or compound (formed by several or many polyps) is called a *corallum*. The individuals of a compound corallum are called *corallites*, each being built by a separate *polypite* which, however, may be laterally united to, or confluent with, its mates. The simple cup-shaped corallum is also spoken of as the *caliculum*. The area enclosed by the outer wall (*epitheca*) of a simple corallum, or an individual corallite of a compound form, is here called the *thecarium*, and within the thecarium various structures are developed as described below. The

* A. W. Grabau Principles of Stratigraphy pp. 930, 943.

upper surface, usually a more or less cup-shaped depression is the *calyx*. The details of the various structural elements of the corallum or corallite, will next be considered.

MORPHOLOGICAL CHARACTERS AND DEVELOPMENT OF THE TETRASEPTATA.

THE EPITHECA. The most fundamental structural character of the TETRASEPTATA as of the ASEPTATA, is the *epitheca* or proper outer wall which encloses the thecarium and within which all the other structural characters are developed. The name originated at a time when the septa were thought to be the fundamental structural characters of corals, and when this outer wall was held to be an additional covering, superadded to the so-called true wall or *theca*. This theca unites the septa in the HEXASEPTATA, where the epitheca is wanting or occupies only a subordinate role. Such a misconception of the relative values of the structural features of the hard parts of corals, was due to the fact that the HEXASEPTATA were made the basis of study of coral morphology, not only of the soft tissues, but of the hard parts as well. This naturally led to the coining of terms in accordance with the nature of these specialized types, and hence a derived or secondary structural feature the interseptal wall, was regarded as the true wall of the corals, and designated the *theca*, whereas the more fundamental and more primitive exoseptal wall, so prominent in the Palæozoic corals, was regarded as an additional feature, and designated the *epitheca*.

The individual development or ontogeny of a considerable number of genera of the Tetraseptata has been investigated, and from these investigations it has become evident, that the epitheca or outer wall is the fundamental morphological character of the hard parts of these organisms. In some cases the earliest stage of the coral is an empty caliculum or cup without septa, these appearing later. This is, however, true only of primitive types, and in the majority of cases the *thecarium*, or solid part of the caliculum enclosed by the epitheca, is characterized in its earliest stage by one or more cycles of septa, their appearance at so early a stage being due to acceleration in septal development.

The fact, however, that in the more primitive types, the thecarium is without septa in the earliest stages, unmistakably points to a derivation of the entire order of Tetraseptata from early aseptate types.

The epitheca has its beginning in the calcareous particles or sclerites which are separated by the cells of the basal part of the young polyp, and which unite to form the minute *basal disk* or *basal plate*. This separation of lime begins with the assumption, by the larval polyp, of a sedentary habit, and in the majority of cases the young polyp becomes cemented by this basal plate to some object of support, which may be a shell-fragment, or the epitheca of an older coral, or even the hardened mud of the sea-bottom.

As the polyp grows, new lime is added to the basal plate, thickening it, and at the same time increasing its size. As a rule, the principal addition, after a time, is made to the margin of the basal plate, which thus increases in area rather more than in thickness. These annular additions to the previously-formed portion, are marked externally by the *lines of growth*, which are one of the most obvious external characters of the wall or epitheca of these corals, and the one by which the epitheca itself is most readily distinguished from other structures. If the rate of addition of calcareous rings to the epitheca is commensurate with the rate of increase in diameter of the polyp, the entire caliculum will assume a flat disk-like form. This is found in certain adult corals of the Palæozoic, such as *Palæocyclus* (text figs. 1, 2) *Microcylus*, *Baryphyllum*, *Combophyllum* and *Hadrophyllum*. In the majority of Palæozoic genera however, the rate of lime deposition is more rapid than the rate of increase in diameter of the base of the polyp, and the newly formed ring of lime will, therefore, not be added to the outer edge of the preceding ring, but to its upper outer border. Thus a succession of rings of carbonate of lime is formed, one above the other, each later one having a slightly larger diameter than the one preceding it. The result of such a regular slight increase in size must inevitably be the production of a conical caliculum, and this is the usual type of form which these corals present. Even in the flat forms cited, the basal portion is not infrequently conical, the expansion into a flat caliculum being a secondary feature, and indicating a later increase in the rate of circumferential growth over the earlier part, a character the reverse of that found in most corals, where the rate of increase in diameter of the polyp diminishes proportionately in later stages.

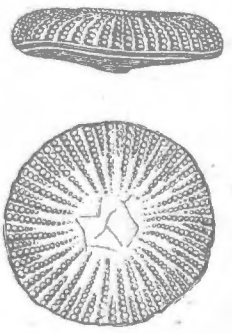

Fig. 1 & 2.

Figures 1 and 2.—*Palæocyclus;* a Silurian corallum showing expansion into a flat disk, because of uniform rate of increase in size and of lime deposition. (The young however is often conical, the flat expansion being a secondary feature) 1. side view; 2. calicinal view. (enlarged about twice).

It might be argued that the production of a flat, disk-like caliculum is the result of the development of the coral upon a hard sub-stratum, either a foreign substance, or a hard sea-botton. There are certain modern corals, such as *Manicina*. which, when found upon a hard solid sea-bottom, show a flat base, while others, apparently of the same species, growing upon a soft bottom into which they sink to a slight degree, assume a conical form of base. This may be a direct adaptation to the environment, here expressed by the nature of the sea-bottom, or it may be the result of natural selection, those forms which have an inherent tendency to form a flat base, i.e. those in which the radial increase is balanced by the rate of lime deposition, thriving upon a hard bottom, but quickly becoming submerged in the ooze of a soft bottom if they happen to find

themselves on such an one, and never growing to maturity. Just the reverse happens to those forms in which the tendency is towards forming a conical base.

But whatever may be the true interpretation of the modern types, this theory of direct adaptation to the nature of the sea-bottom does not hold for the Palæozoic forms in question, for the flat-bottomed *Microcyclus* is found in the same strata with the conical *Stereolasma*, and the form of the caliculum is in each case peculiar to the organism and not the product of adaptation.

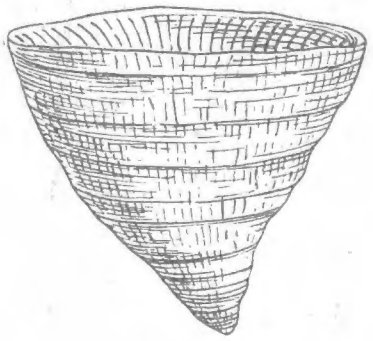

Fig. 3.

Fig. 3. A broadly conical caliculum:

If we recognize that the form of the caliculum is an expression of fundamental characteristics, we can use it as a basis of varietal if not specific distinction. For it must be evident, that individuals in which the rate of expansion is rapid, and which therefore produce a broad conical form (text fig. 3) belong to another genetic series than those in which the expansion is a slow and gradual one, and the form of which is, in consequence, that of a long cone with relatively small apical angle (text fig. 4.) This difference in rate of expansion may not be of sufficient importance to warrant generic or even specific distinction, unless accompanied by variations in other characters. Indeed, forms otherwise alike, may vary in this respect in different localities, and this variation may be induced by different environmental conditions, such as the composition of the water, the food supply etc. which affect the physiological condition of the polyps, this effect finding expression in the relative rates of increase in diameter and of lime separation. Where such variation, however, exists in the same locality, it must be regarded as expressing a fundamental, even if slight, inherent difference in the organism, and may lead to the development of distinct genetic series.

Fig. 4.

Figure 4. A narrowly conical caliculum.

Not all, in fact not even a majority of the Tetraseptata are characterized by a regular and uniform rate of growth which results in a uniform expansion of the caliculum. More commonly the expansion proceeds regularly up to a certain point, when it decreases in rate, or what is more usual ceases altogether. Therefore the rings of calcium carbonate which build up the epitheca, are all of the same diameter, and consequently they are added one above the other. The result is the production of a cylindrical caliculum with a conical base. (Text figs. 5 and 6). The diameter of the cylinder depends of course upon the period at which expansion ceases. Usually, where the expansion during the early stages was a rapid one, producing a low conical base, the diameter reached, when cylindrical growth commences, is large, (text

fig. 5), whereas, with a slow rate of expansion, the diameter usually remains a moderate one (text fig. 6). In many Tetraseptata, the period of cylindrical growth is succeeded by one of progressively diminishing diameter, the caliculum thus tapering towards the calicinal margin (text fig. 7). In other cases the contraction of the polyp is a sudden one, and the caliculum has the appearance as if it were covered by a lid, the summit of which contains a small calyx. A diminishing diameter in all cases implies a contracting polyp, and this must generally be regarded as indicative of a period of senescence. Such a condition may, however, also be pathologic, when through some injury, or under unfavorable conditions, the polyp degenerates in size. Sometimes, after such a period of contraction, the polyp will expand again, thus producing the appearance of a succession of superposed cones. In other cases the contraction though slight, occurs at frequent intervals, followed by renewed expansion. Then a very irregular caliculum is produced (text fig. 8). Irregularity of growth is shown in most large calicula, though in normal individuals this irregularity is not a very marked one, being indicated only by a succession of concentric growth wrinkles.

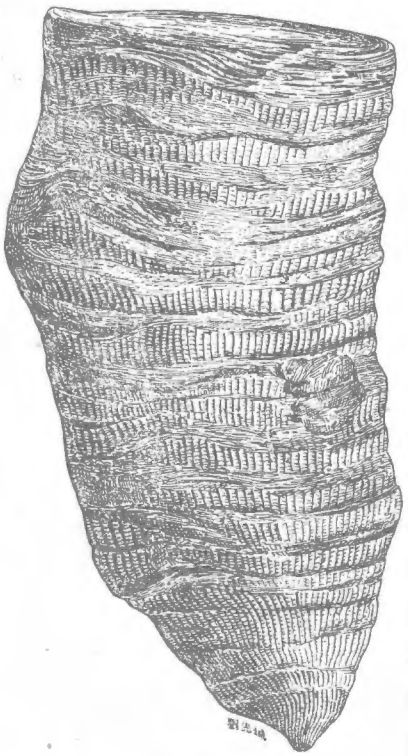

Fig. 5.

Figure 5. Broadly cylindrical caliculum with conical base, showing cessation of expansional growth after completion of early stages. (E & H)

A curved form is characteristic of many simple Tetraseptata, (text fig. 6, Pl. I figs, 5a, 17a, 18a) especially those of slender conical growth. Curvature of the caliculum implies inequality in the thickness of the rings of calcareous material of which the epitheca is built, the side where the deposit is thickest becoming the convex side. Usually this is the side on which the cardinal septum is situated, but it may also be the opposite one (where the counter septum is located) or one of the alar regions. The change in direction, due to this curvature, may sometimes be 90° or more, so that the plane of the calyx comes to lie paralled to the axis of the young corallum (*e.g: Pinnatophyllum norini*, Grabau.)*

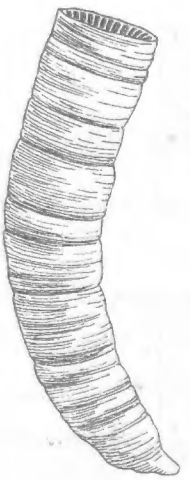

Fig. 6.

Figure 6. A narrowly cylindrical caliculum, with conical base, showing cessation of expansional growth at an early stage, the rate of expansion being relatively slow.

Abrupt changes in the direction of growth occur as the result of accident, usually after the original fixation has been broken, and the

* Described and figured in a subsequent fascicle.

coral become prostrate. The new direction of growth is not infrequently at right angles to the old (text fig. 9.)

Mode of Attachment. In many of the corals which do not reach a large size, only the extreme initial portion is attached to foreign objects, while in other cases there may be no attachment at all, the coral remaining free throughout life. When the initial tube is long and slender it may be further attached by one of its sides to the object of support. Sometimes the development of a mass of epithecal tissue may result in the production of an irregular base. This may be wholly a matter of environmental influence, the same species of coral building a strong base in agitated waters, while in quiet waters little or no secondary supporting substance is added. On the other hand, such structures may be more fundamental, those individuals which possess the ability or tendency toward building a broad base, surviving in rough water, while others, not so endowed will perish, or develope only where the water is relatively quiet.

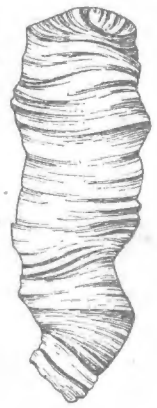

Fig. 7.

Figure 7. An irregular cylindrical caliculum contracted at the calyx.

In a considerable number of corals, firm anchorage is brought about by the development of root-like proliferations from the edge of the growing cup. These proliferations will finally develope into a tube, and subsequently even become solid. Then as the corallum increases in length, they are left behind, and in the adult individual they have the appearance of basal extensions of the epitheca. They were however built from the edge of the caliculum when the individual was young.

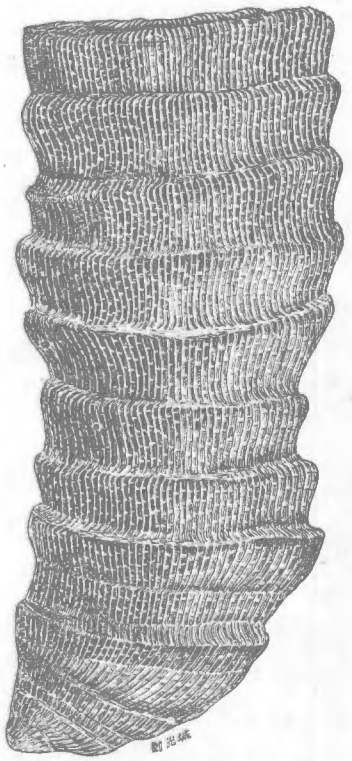

Fig. 8.

Figure 8. A caliculum showing repeated slight contractions followed by a resumption of expansional growth. (E. & H.)

These rootlike proliferations are characteristic of a number of different generic types, and they do not necessarily indicate relationship of the forms in which they occur. They are to be regarded rather as parallal developments, and may occur in some species of a genus and be absent in others. Thus they are found in *Amplexus spinosus*, (Plate I, figs. 22, 23) but are wanting in other species of that genus. When they are broken away, their former existence is generally indicated by a scar or a node on the surface of the epitheca. Examples of genera in which they are usually or always developed are: *Rhizophyllum* and *Omphima*, though even in

these genera they may not always occur, or at any rate are developed in varying intensity.

THE EPITHECA OF COMPOUND FORMS. In compound Tetraseptata, which are generally produced by the formation of buds on the margins of the calyx of the mother corallite, the epitheca characterizes each new individual. If the corallum is a loosely growing mass, the epitheca of each corallite will show its normal characteristics, similar to those in the simple corals. The only modification that may arise, is the formation of periodic expansions or proliferations, which will bind adjoining corallites into a more resistant mass. These proliferations are always formed at the edge of the calyx, by an expansion of the polyp. Subsequent contraction of the polyp to usual dimensions, and continued lime deposition will leave the expanded part behind as a proliferation from the side of the corallite (*Eridophyllum*).

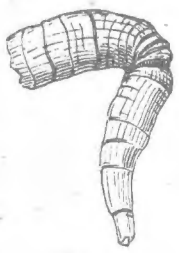

Fig. 9.

Figure 9. A slender caliculum showing abrupt change in direction of growth, the angle of change being more than 90 degrees (de Kon).

When the corallites of a compound form are closely crowded, so that the individuals assume prismatic form, the epitheca of adjoining prisms will be in close contact, and may indeed become amalgamated, though generally the corallites will separate between the epithecal layers. At the calicinal margin, the double epithecal wall will frequently assume a zigzag form because of the alternate position of the principal septa in the adjoining calices, the wall bulging outward between the septa, that is into the adjoining corallite. (text fig. 10).

It may also happen that the epithecal wall between the corallites becomes suppressed, because the septa assume an exert growth, as a result of which the calices of adjoining corallites become confluent by their septa. This is especially marked in the Upper Devonian genus *Phillipsastæa*, which is derived from a form the walls of which are normally developed. It is however not confined to this genus, but may appear in end members of distinct genetic series. In compound forms of closely crowded corallites, the epitheca of the exposed portion of the outer members of the colony commonly unites to form a continuous *peritheca*, which envelopes the entire colony.

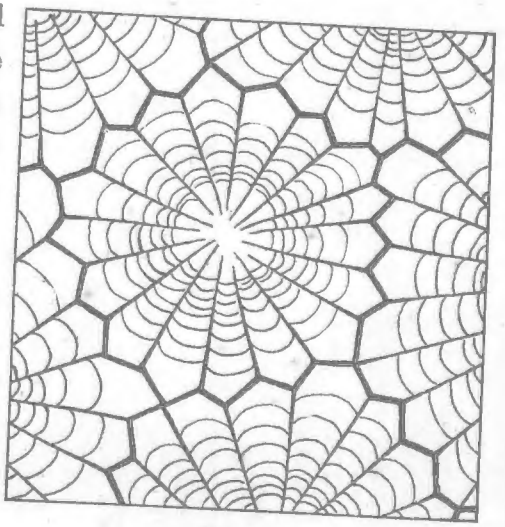

Fig. 10.

Figure 10. A group of corallites from a crowded compound corallum i.e a coral-head showing zigzag form of epithecal wall; (*Acervularia*).

THE SEPTAL GROOVES. The epitheca of a young caliculum, or of an adult in which little subsequent

thickening occurs, shows a series of longitudinal grooves, which mark the position of the septa, each groove corresponding to the center plane of a septum. This is due to the fact that in simple corals the epitheca bulges outward between the septa, the position of the latter thus being indicated by the depression between the bulgings. These bulgings are sometimes falsely spoken of as costæ. True costæ are the extrathecal prolongations of the septa, and are formed only in the Hexaseptata and allied types (text fiig. 11b, cos.) These grooves on the outside of the tetraseptate caliculum may also be spoken of as costal grooves. (Text fig. 11a, cq).

Development of the Septa. In all Tetraseptata there are four primarily, a variable number of secondary, and a corresponding number of tertiary septa. In most cases the primary and secondary septa become of equal appearance in the adult, and in many descriptions they are both referred to as primary, while the tertiaries are called secondaries.

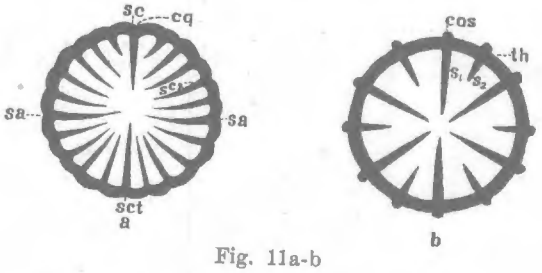

Fig. 11a-b

Figure 11a. Diagrammatic section of a tetraseptate coral, showing septa and septal grooves, (cq) the latter formed by the bulging of the wall (epitheca) between the septa. 11b. Similar section of a hexaseptate coral, showing the extension of the septa into extramural rigdes or costæ (cos.)

The four primary septa consist of the *cardinal*, the *counter*, and two lateral or *alar* septa, These appear either simultaneously (in accelerated types text fig. 12) or the cardinal and counter septa appear first dividing the thecarium by a median dorso-ventral partition into two equal lateral portions, (text fig. 13). In many primitive forms, the septa appear first as ridges on the inside of the epitheca, (text fig. 14) and by subsequent enlargement these may meet in the center. In more accelerated types, the cardinal and counter septa extend far towards the center or even meet at a very early stage. When the alar septa appear, they divide the caliculum into four quadrants, two of which are classed as cardinal, and two as counter quadrants, (text fig. 15 cq, and ctq, respectively).

In some forms the alar septa may appear equidistant from the cardinal and the counter septum, when the resulting quadrants are equal. Very often however they appear nearer to one or the other main septum, usually the cardinal one, thus leaving the counter quadrants of greater size than the cardinal. If that is the case the first of the secondary septa will appear in the counter quadrants, (text fig. 16). It is not yet positively known that the reverse obtains, though genera and species with highly accelerated cardinal quadrants (as compared with the counter quadrants) are known, and in these it might be supposed that the cardinal quadrants, when first developed, are the larger, and that the first secondary septa appear in the cardinal quadrants. This will have to be settled by a study of the young of such forms.

In the counter quadrants, the first pair of secondary septa appears next to the counter septum and each succeeding pair appears between the last-formed one, and the alar septum, in other words, in the space next to the alar septum. This is the main growing part, continuing to increase in size until it is large enough for the appearance of a new secondary septum, (text fig 17). As each new septum of the counter quadrants appears, it seems to branch off from the alar septum at a somewhat higher level when

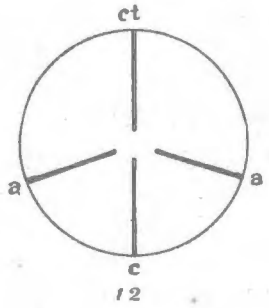

Fig. 12.

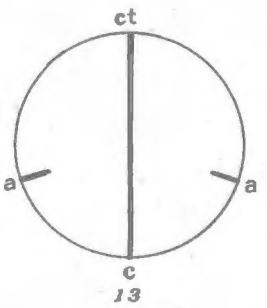

Fig. 13.

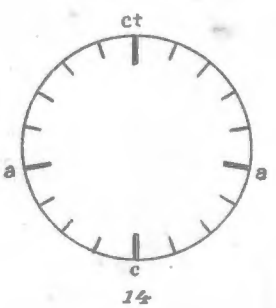

Fig. 14.

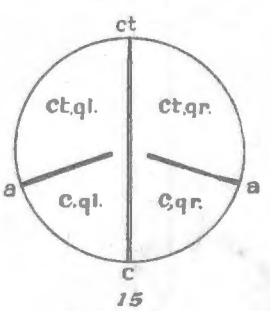

Fig. 15.

Figure 12. Diagram illustrating the simultaneous appearance of the four primary septa.
Figure 13. Diagram illustrating the earlier appearance of two of the primary septa cardinal (c) and counter (ct)), followed by the alar (a).
Figure 14. Diagram of primitive coral showing the primary and second septa in the form of short ridges.
Figure 15. Diagram illustrating the four quadrants.
c - cardinal septum; *ct* - counter septum; a,a - alar septa;
ctql - left counter quadrant; ctgr - right counter quadrant;
cql - left cardinal quadrant; cqr - right cardinal quadrant.

viewed laterally, and the entire arrangement of the secondary septa is a pinnate one with reference to the alar septum. This is well shown in the disposition of the costal grooves on the exterior, (text fig. 19. Pl. I, figs. 2a, 14a). When the counter quadrants are highly accelerated the tertiary septa may begin to appear before all the secondary septa are formed (text figs. 18). Those next to the counter septum on either side may

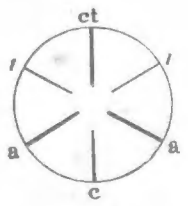

Fig. 16.

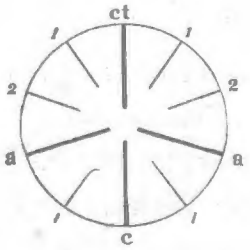

Fig. 17.

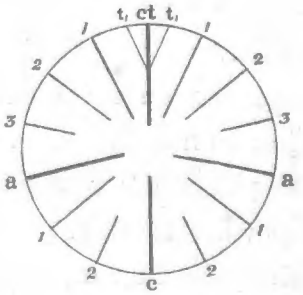

Fig. 18.

Figure 16. Diagram showing the appearance of a single pair of secondary septa (1) in the counter quadrants.
Figure 17. Diagram showing the appearance of a second pair of the secondary septa (2) in the counter quadrants simultaneously with the first pair (1) in the cardinal quadrants.
Figure 18. Diagram showing order of appearance of secondary septa; 3 pair in the counter quadrants, and 2 pair in the cardinal quadrants. A pair of tertiary septa (t) has also appeared in the counter quadrants.
c - cardinal; *ct* - counter; *a.a* - alar septa.

appear very early and assume almost the character and dignity of secondary septa. A peculiar alternation of secondary and tertiary septa is shown in *Cyathaxonia* where the corresponding tertiary septal pair appears after each secondary pair and behind it, i.e. on the counter side in the counter quadrants, and on the alar side in the cardinal quadrants. This is more fully described in the discussion of that genus.

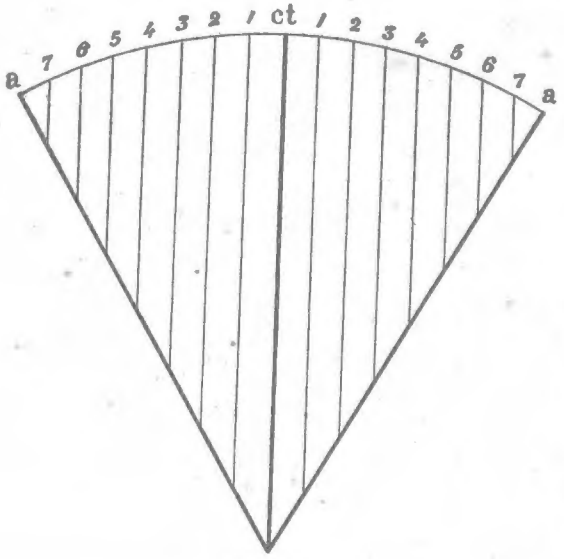

Fig. 19.

Figure 19. Diagram showing order of appearance of secondary septa (1-7) in the counter quadrants parallel to the counter septum (*ct*) and branching in a pinnate manner from the alar septa (a,a).

In the cardinal quadrants, the new septa appear always next to the cardinal septum where the growing end lies, that is, the increase in circumference in this part of the caliculum, takes place mainly on either side of the cardinal septum, and when the space is wide enough, a secondary septum appears in it, (text figs. 17, 18). The space between this and the alar septum increases so little as a rule, that there remains essential parallelism between the alar and secondary septa of the cardinal quadrants, and between succeeding secondary septa as well. If a slight divergence occurs, a tertiary septum will occupy the space. As each new pair of septa of the cardinal quadrants thus appears at a higher level than the preceding, when viewed laterally, a pinnate form of arrangement of these septa with reference to the cardinal septum is produced, and this is well shown by the septal grooves of primitive species, (text fig. 20, Plate I, fig. 15a).

There are thus four principal growing points in each corallum, one on the counter side of each alar septum, and one on each side of the cardinal septum, and in these places the new secondary septa appear. The new septa are frequently joined on their inner edges with the preceding ones, and in some cases all the septa of a quadrant may be thus joined, producing a quadripartite septal grouping (text fig. 21). This emphasizes the growing areas, which then often appear as broader gaps than those between the older septa. The spaces between the latter may, moreover,

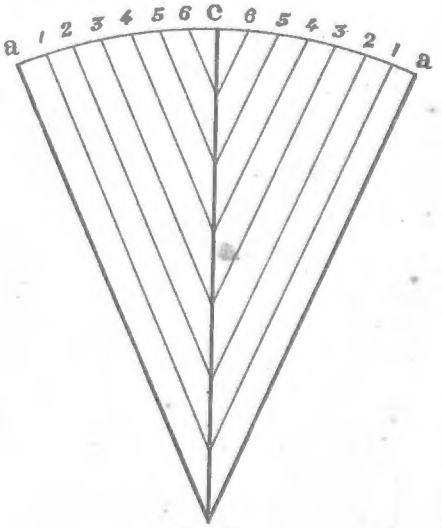

Fig. 20.

Figure 20. Diagram showing the order of appearance of the secondary septa (1-6) in the cardinal quadrants, their pinnate mode of divergence from the cardinal septum (c) and their parallelism to the alar septa (a,a).

be occupied by tertiary septa and by dissepiments. Such gaps are often erroneously spoken of as *lateral fossulæ*. They are however, more properly called *alar pseudo-fossulæ*. They occur in the young stages of the majority of the Tetraseptata, always being located on the counter side of the alar septa. They thus represent merely a stage in individual development. If they persist into the adult stage, the species must be regarded as in this respect retarded in development. (Plate I, fig. 14b).

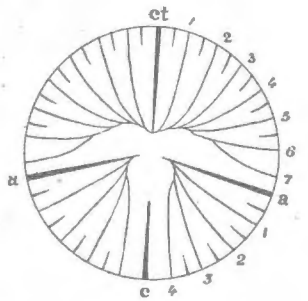

Fig. 21.

Figure 21. Diagram showing the usual arrangement of the septa in the young or primitive adult tetraseptate caliculum, the secondary septa joining the counter septum (ct) in the counter quadrants, and the alar (a,a) in the cardinal quadrants. There are seven secondary septa in each counter quadrant the youngest (no. 7) next to the alar septum where a gap, the alar pseudofossula remains on each side. In the cardinal quadrant 4 secondary septa occur, the youngest (no. 4) being next to the cardinal septum (c), on the sides of which appear the cardinal pseudofossulæ which by abortion of the cardinal septum, unite to form the true fossula. Tertiary septa occur between the older secondaries.

The corresponding *cardinal pseudo-fossulæ* likewise represent a normal stage in individual development, and their persistence into the adult, together with the pinnate arrangement of the adjoining secondary septa, is to be regarded as an indication of retardation in development, (*Aulacophyllum*, *Pinnatophyllum* etc.) or of long persistence of the cardinal area in a condition of growth. These two cardinal gaps often become united into a simple *true fossula*, by the partial or nearly complete abortion of the cardinal septum. (*Zaphrentis* etc.)

THE FOSSULA AND ITS SIGNIFICANCE. The true fossula is always formed by the abortion of the cardinal septum, though this may not always lie on the side of the greatest curvature. When it lies on one side, the individual is probably pathologic, while its position on the concave side may indicate racial senility. In normal individuals the cardinal septum is one of the first, if not the first to be developed, and is a prominent structure throughout the early stages of development. In a very large number of types it remains prominent throughout life, though in very old individuals, or in a few special members of a species, in which it normally is fully developed, it may become aborted towards the last. Thus a fossula is formed only in the adult or old age of many species, or in specialized mutations of some species only. In all cases, when it occurs, it is a feature added later in the life of the individual, usually not until the adult stages. Again in some races, the early members are wholly devoid of a fossula, this appearing only in the adult of some specialized members at a late stage of their existence. Thus in the *Streptelasmaidæ*, it appears first in the Devonian, and then only in specialized groups. In one family however, the *Zaphrentidæ*, the fossula is a feature acquired early in the life of the group and early in the ontogeny of the individual. At any rate, it is a fully fixed character in the adults of the various generic groups of that family, though probably lacking in the young of all of them. In some of the large cylindrical forms with many

tabulæ it has become so marked a feature, that the tabulæ are affected at that point, being produced backward into a funnel-form emargination or *siphonofossula* (*Siphonophrentis, Siphonophyllia*). This peculiar structure leads one to think that its development is coincident with, or determined by, the concentration of certain structures or organs at the corresponding point in the fleshy polyp.

The development of the true fossula thus always indicates specialization, and it is a structure which may appear in many if not all genetic series, early in some, late in others. Therefore individuals or species with a fossula are always more specialized than related forms without a fossula, while those in which the fossula appears early, are more specialized than those in which it appears late. Nor can a form in which the fossula is feebly or not all developed in the adult, belong to the same genetic series as one in which it is strongly developed, if that species occurs at a lower geological horizon, even though we may designated it by the same generic name. It represents at the least, a retarded lateral branch.

Again it is unwise to class two species in the same genus, if one has a well developed normal fossula in the adult, while the other has such a fossula in the young stage, but developes a siphonofossula in the adult. Thus true *Caninia* never passes beyond the normal fossula in the adult, but *Siphonophyllia* passes through a *Caninia* stage, developing a siphonofossula in its own adult stage.* A young *Siphonophyllia* may therefore be mistaken for a *Caninia*, unless its immature character is recognized. Above all, the much too common practice of classing all forms with a well-developed fossula as *Zaphrentis*, must be abandoned, in view of the fact that a fossula does not indicate genetic relationship, but indicates only a stage in development, in onto- or in phylogenesis, a stage reached sooner or later in practically all genetic series.

Thickening of Septa. The septa of the Tetraseptata are subject to thickening by the addition of organically deposited lime (stereoplasm). This may affect the entire septum, which then assumes a more or less wedge-shaped form, with the thin end at the center, or the thickening may proceed so far, that adjoining septa are nearly or quite in contact at their thickened ends, or for some distance of their lengths. Sometimes only the septa of one pair of quadrants are thus affected as in the case of *Pinnaxophyllum norini*,** where those of the cardinal quadrants are alone thickened. This may lead to unequal subsequent erosion of the corallum, and, in the species mentioned, individuals preserving only the cardinal quadrants are sometimes found. In other cases all the septa may be equally reënforced by stereoplasm. Sometimes the thickening is confined to certain

* These genera are described in a subsequent fascicle of this volume.
** Described in a subsequent fascicle.

zones. Thus in *Pinnatophyllum* (*Heterocaninia*) *tholusitabulatum* (Yabe and Hayasaka), the thickening only begins about one third the septal length from the periphery, and dies away again towards the center. In this species too, it not infrequently happens, that the thickened portion is alone preserved, the outer zone, not thus reënforced, being worn away before the corallum becomes embedded. In that case a false impression of the character of the corallum is obtained. Sometimes the thickening is confined to a certain narrow zone near the inner ends of the septa, this zone then appearing as an inner wall (stereotheca), easily distinguished, however, from the true inner wall by the fact that the septa extend beyond this zone (see below). But the most remarkable case of thickening on record, is that found in the genus *Tachylasma* known at present only from Chinese rocks, where it is represented by three species. Here, in the more primitive forms, the alar and the first pair of secondary septa of the counter quadrants are thickened, while in the other species these and certain other pairs are thus reënforced. The result is the production of a unique and distinctive septation unlike any known in other types. (Text fig. 50, and Plate I, figs. 2b, 3a, b., 4, & 13b).

It should be recognized that thickening of the septa is confined to their older portions (i.e. those in the lower part of the caliculum) such character not appearing in the calyx, where, however, those septa which are thickened more than others may project more prominently.

The development and subsequent thickening of the septa is brought about in the following manner. In the young polyp, there is developed a series of radial folds or creases of the basal ectoderm, and there the calico-blasts or lime-secreting cells are especially active. As both sides of this fold deposit lime, the septum will come to consist of two distinct layers or plates which join in the center. This central junction is generally indicated in section by a dark line, which marks the junction of the two plates of which the septum is composed. As the septum grows by further addition of lime over its outside, this double character becomes more evident, especially if, as sometimes happens, the outer layers become silicified during fossilization, while the inner remain calcareous and are frequently dissolved away. On the exterior of the corallum the central line of the septum is general indicated by the costal groove, and between adjoining grooves the outward bulging epitheca may also become thickened by layers of stereoplasm continuous with those applied to the sides of the septum. If these layers are closely applied, a thick epithecal wall results, but they may also be loosely applied, when they have the character of dissepiments. (Text fig. 22).

Modifications in the Length of the Septa. If septa grow rapidly in length, they become crowded near the center, and a twisting of their inner ends may result.

When this is strongly developed, a well-marked median elevation or *streptocolumella* will result. This is well shown in the genus *Clisiophyllum* and may be partially developed in certain cyathophylloids, where it does not occur normally, indicating specialization in this direction.

The reverse of this process is seen in a shortening of the septa, which in normal forms, and in the young, meet near the center. When the septa fail to reach the center in the adults of all but primitive forms, this condition is usually due to a failure of the ends to develop. The central non-septate area may be occupied by tabulæ, upon the surfaces of which the septa die away as low ridges. This is most typically developed in the genus *Amplexus* but is by no means confined to it. Indeed this *amplexoid character* as it is designated, may occur in all lines of development. Thus in the *Streptelasmaidæ*, it makes its first appearance in the Devonian, and this leads apparently to the true *Amplexus*, which is most typical of the Mississippian (Dinantian). Among the *Zaphrentidæ* it is seen in *Siphonophrentis* of the Middle Devonian, and *Caninia* and *Siphonophyllia* of the Dinantian and Moscovian. In the *Cyathophyllidæ*, it is found in *Campophyllum* and some other genera. In each case it must be considered a specialization in a given direction, and its occurrence in different genera is a case of parallelism in development, and does not indicate relationship. The center of the caliculum may also become occupied by cystose structure as in the Devonian genus *Mesophyllum*. In some cases the septa become indistinct or discontinuous at the periphery, their place being taken by cystose structures. Such septa are spoken of as *recessive* (German, rückgebildet) and so far as known, this represents a secondary feature, the septa of the young reaching the periphery in a normal manner. It is seen in *Merophyllum* Grabau and in *Endophyllum* and *Spongophyllum*. Again it is seen in the specialized Dinantian and Carbonic genera *Lithostrotionella* and especially in *Lonsdaleia* which are derived from genera with normal septa.*

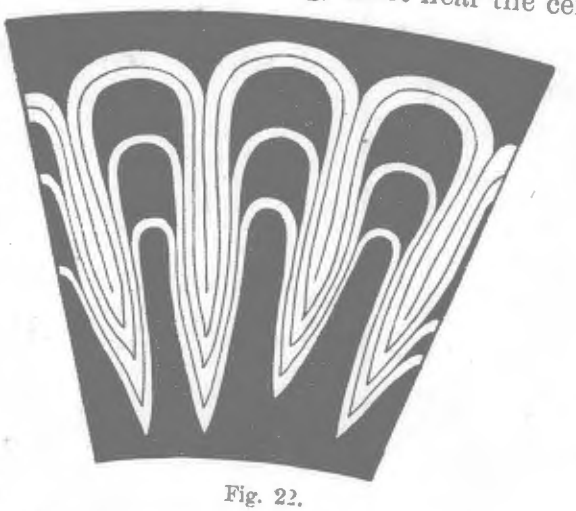

Fig. 22.

Figure 22. Diagram of a part of a transverse section of a tetraseptate caliculum (much enlarged) showing four septa formed by addition of successive layers of stereoplasm. Some of these layers do not reach the outer region but form dissepiments.

CARINÆ. These represent local thickenings of the septa, generally in the form of ridges more or less equally disposed upon the sides of the septum. Generally there are

* These genera are discussed in subsequent fascicles.

corresponding ridges on both sides of a septum, and if these are obliquely or vertically placed with reference to the plane of the calyx, they appear as regularly disposed cross-bars on the septa, being visible as such also in transverse section. The Devonian genus *Heliophyllum* shows these in greatest perfection (text fig. 23) for there they have become fully established, and are to be regarded as a fixed generic character. In the young *Heliophyllum* they are however, not found; they make their appearance gradually with the growth of the individual, and their number on each septum is commensurate with the age of the individual. When the development of this feature is a slow process, their appearance will begin late in life, and the adult will have comparatively few carinæ; when it is a rapid one, they will appear early in ontogeny and will be numerous in the adult. Thus their relative number in the adults is indicative of the relative acceleration in development of the corresponding individuals. It must, however, be clearly understood, that carinæ are not indicative of generic relationship any more than a fossula is. Thus the common practice of classing all forms with carinæ as *Heliophyllum*, is unwarranted, and has resulted in the placing of the original genotype of *Zaphrentis* in this genus, because it has carinæ.* Carinæ represent a stage in development, and occur in many genetic series, sometimes appearing only in the adults of a few forms, in which normally they are not developed, and then having only a varietal significance Such is the case in *Pinnatophyllum scyphus* variety *carinata* Grabau, of the Devonian (North America). In other cases they characterize a species as in *Zaphrentis cornicula* of the Devonian, one of the few species of that genus in which they occur. Finally they may be so thoroughly established, that they become a generic character, reappearing in all the species of that particular genetic group. Such is the case in *Heliophyllum*, a derivative of *Cyathophyllum*.

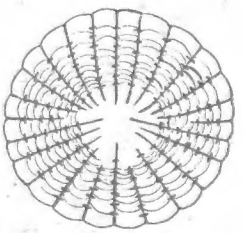

Fig. 23.

Figure. 23. Cross-section of *Heliophyllum* showing the carinæ on the septa and the dissepiments between them.

There is, however, another group of carinæ, which has a horizontal position on the sides of the septa. These carinæ may, or may not be symmetrically placed upon the sides of the septa, and become visible only in vertical or oblique sections. (*Lopholasma*, and *Lophocarinophyllum* Plate I, figs. 6-11, & 18c, text figs. 54-63). Sometimes the outer margins of these carinæ bend upwards, and then they will appear as recurving hooks on the sides of the septa in oblique sections (Plate I, fig. 9d). Transverse sections in such cases may cut the upturned edge of the carina, this then appearing as a supplementary septum, or the appearance of a double septum may be produced (Plate I, fig. 5b).

* M. O'Connell, loc. cit.

Dissepiments and Cystosepiments. Dissepiments appear in section as connecting plates between the septa, and generally are trough-like structures placed obliquely with the bottom sloping inwards and the concavity towards the polyp. Typically they may be regarded as the continuation, across the intervening space, of the layers of sclerenchyma added to the sides of the septum (text fig. 22, p. 16). Towards the center they may converge into tabulæ, or they may be independent of the tabulate area if such is present. In some cases they are arranged in such a continuous series that they appear to form an inner wall bounding a central area (sclerotheca) but this is easily distinguished from the true inner wall by the fact that the septa project beyond it into the central area, which is not the case in forms with a true inner wall. *Cystosepiments* are more or less regular lines of cysts formed between the septa. They are convex towards the polyp, and mark local withdrawal of the soft tissue and the deposition of a closed cyst or vesicle of stereoplasm. When typically developed, they are readily distinguished from dissepiments, but they may grade into them.

Tabulæ. These are more or less horizontal transverse plates confined to the central portion of the corallum. They may grade laterally into dissepiments, or be distinctly bounded by an inner wall, or they may end more or less abruptly, when the periphery is formed by a cystose zone. In some cases they extend entirely across the thecarium. Their presence always indicates specialization in the normal septate caliculum. In the young individual they are, as a rule, wanting, developing only in the later stages. In primitive or unspecialized forms, they are absent, or only one or a few may develope in the adults. Thus in typical *Zaphrentis* they are wanting, or only a single tabula appears in the adult. In the more specialized *Heterophrentis*, a few tabulæ are formed, the earlier ones at considerable intervals, the later more closely crowded. In the still more specialized *Caninia* and other late Palæozoic genera, they occur abundantly. In most families they are developed in the more specialized genera. When they are very rapidly built, they may be incomplete, extending only part way across the central space and coalescing with a previously formed tabula. In certain forms they become elavated tent-like in the center (*Acrophyllum*) and this may be further complicated by a spiral twisting of the elevated portion (*Lonsdaleia* etc.) or by the formation of a solid median rod or columella (*Lithostrotion*).

Cystose Structure. This is abundantly developed in many genera, occuping either a portion of the thecarium or filling it completely. In the latter case, septa may be developed only upon the surface of the cysts, the formation of the cysts preceding that of the septa (*Microplasma*) or they may form between the septa, later replacing these more or less completely (*Actinocystis*). Again they may form only in the outer zone (*Endo-*

phyllum, Lonsdaleia), or in the inner zone (*Mesophyllum*). Cysts are always convex towards the polyp which built them, and represent local indrawing of the fleshy portion, with the deposition of a layer of lime corresponding to the concavity produced by such a withdrawal. In the majority of cases, cysts are small and numerous, but they may locally become of considerable size. Not infrequently the outer coarse cystose zone may be more or less destroyed, together with the epitheca, in the process of fossilization, or subsequently, when the exterior of the corallum will present a very rough appearance (*Blothrophyllum*).

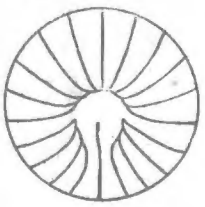

Fig. 24.

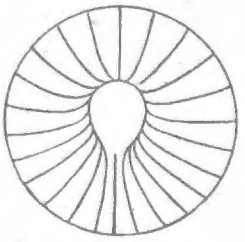

Fig. 25.

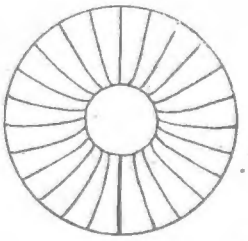

Fig. 26.

Figure 24. Section of a young stage of *Crepidophyllum*, showing the union of the septa by their inner ends into three main groups.

Figure 25. Section of an adult *Crepidophyllum* in which the alar gaps have been bridged, forming a horseshoe-shaped inner wall, open on the side of the cardinal septum.

Figure 26. Section of adult *Eridophyllum* showing complete inner wall not penetrated by the septa.
(Note: In these sections carinæ and dissepiments are omitted).

The Inner Wall. This name has been given to various structures of diverse origin, and without genetic relationship. It will then first be necessary to define the several types thus designated, and determine their significance in terms of classification.

Mr. G. E. Andersson, while a student in my laboratory, discovered by the study of serial sections, the origin of the true inner wall of *Crepidophyllum* and *Eridophyllum*. He found that the original quadripartite arrangement of the septa persisted into the adult, but with the modification that the septa, which originally sloped towards and coalesced with the primary septa and with one another, became radial, without however losing their connection with the preceding septum. This was effected by the bending, at right angles, of the inner ends of the septa, the end of each bent portion adhering to the preceding one at the elbow (text fig. 24). Thus the ends of the septa of the counter quadrants were bent abruptly towards the counter septum from each side, those next to it uniting with it, and each succeeding septum joining the preceding one. The septa of the cardinal quadrants in like manner bend abruptly towards the alar septa joining them and one another in each quadrant. Thus an inner wall is produced with, however, three gaps in it, one at each alar pseudo-fossula, and one at the cardinal fossula. The alar gaps are bridged over by dissepiments completing the wall in this portion. In *Crepidophyllum* the cardinal gaps remain open. Thus an inner wall, with only a cardinal opening is

produced this wall sometimes assuming a horse-shoe shaped outline (text fig. 25). In *Eridophyllum* on the other hand, while the wall is of the *Crepidophyllum* type in the young, it becomes more specialized in the adult, in which the cardinal gap is also bridged over, so that it is complete throughout (text fig. 26). The result of this mode of growth is, that the primary and secondary septa, radial in the adult, join the inner wall, but do not pass beyond it, the inner zone, which is generally occupied by tabulæ, being entirely free from septa. The tertiary septa do not, as a rule, reach the inner wall. In the adult then, the perfect inner wall forms a central tube into which the septa do not penetrate. The name *phyllotheca* may be applied to such a true inner wall, formed primarily by the septa themselves.

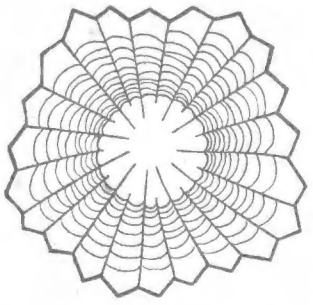

Fig. 27.

Figure 27. Cross-section of a corallite of *Acervularia* showing the crowding of dissepiments near the center to form a false inner wall (sclerotheca) with the septa extending beyond it.

A second type of inner wall may be formed by the alignment and crowding of the dissepiments between the septa at a point partway between the margin and the center. This does not form a true inner wall, though it simulates one. The principal septa (primary and secondary), however, extend beyond this circle of dissepiments towards, or to the center (text fig. 27). This type of false inner wall or *sclerotheca*, as it may be called, is homologous with the theca of the *Hexaseptata*, where the septal ends extend beyond it, i.e. outside of it, forming the costæ. It is formed by separately deposited sclerites between the septa, the latter having no part in its formation. This type of pseudotheca is found in *Diplophyllum* Hall, in *Lithostrotion* Llwyd, in *Acervularia* Schweigger, and in other genera.

A third tpye of false inner wall (pseudotheca) is formed by the thickening of the septa at a certain point, this corresponding in position in all the septa (text fig. 28). When the thickening proceeds so far that the thickened portions of adjoining septa touch or even coalesce, the appearance of an inner wall is produced, but this has no relationship to the true inner wall or *phyllotheca* nor to the dissepimental wall or *sclerotheca*. It may be called a *stereotheca*, formed by the local deposition of an excess of stereoplasm. It is found in certain American and European Devonian species of *Prismatophyllum*, and in *Phillipsastræa* from the Upper

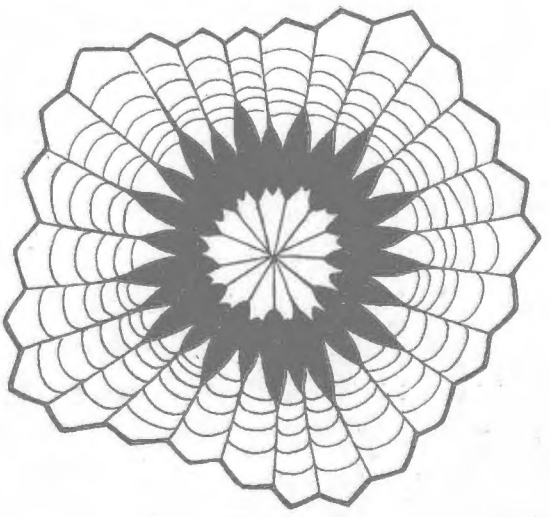

Fig. 28.

Figure 28. Section of a corallite of *Prismatophyllum* showing the formation of a false inner wall (stereotheca) by local thickening of the septa.

Devonian of Europe, and especially in *Pachyphyllum*. Often the position of this type of pseudotheca corresponds to an abrupt change in the shape of the calyx from a nearly flat outer, to a steeply depressed inner area. This form of calyx also occurs in *Acervularia* where the sclerotheca of dissepiments is situated at the point of change in slope.

Finally there is a fourth type of inner wall decidedly different from those previously described. This is formed in the Devonian genus *Depasophyllum* Grabau, and in the Dinantian (Lower Carboniferous) species *Diphyphyllum concinnum* (text figs. 29, 30). In these forms the tabulæ bend down around the edges to form a sort of shallow inverted cup, or a structure resembling the cover of a round pillbox. A series of such structures, set one above the others, forms by the vertical edges of the successive elements, a continuous inner wall, which is analogous to the true inner wall formed by the ends of the septa. The rims of these successive inverted cups are indented from without where the septa join them. Between the septa they are lobed outward, thus having a scalloped appearance. The septa thus do not penetrate into the inner margin or may extend only as short ridges on the surfaces of the tabulæ. This type of wall may be mistaken for a *phyllotheca* or true inner wall of the first type. It can, however, generally be distinguished from that by its scalloped or outward-lobed character between the septa.

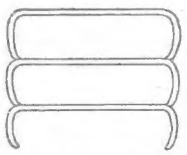

Fig. 29.

Figure 29. Diagrammatic longitudinal section of the central tabulated area of a caliculum in which the inner wall (cyathotheca) is formed by the down-bending of the margins of the tabulæ.

This type of inner wall may be designated a *cyathotheca*, because it is formed by a succession of superposed shallow inverted cups. When the outer septal zone (which is often narrow) is destroyed, the wall formed by these superposed cup rims has externally the aspect of a fluted column (text fig. 30).

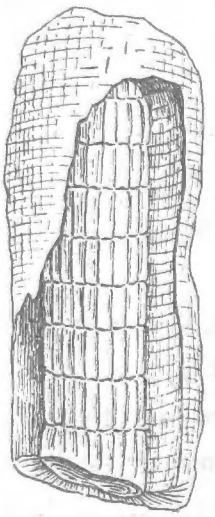

Fig. 30.

Figure 30. A part of a corallite of *Diphyphyllum concinnum* Lonsd. with the exterior partly broken away showing the inner fluted wall (cyathotheca) formed by the successive superposition of tabulæ with their margins bent downwards. (After de Koninck).

There are thus at least four distinct types of inner wall in the Tetraseptata. These may be summarized as follow:

1. True inner wall or *phyllotheca* formed by the ends of the septa which are bent at right angles. Ex: *Crepidophyllum Eridophyllum.*
2. Dissepimental inner wall or *sclerotheca*, formed by the arrangement, in a continuous row, of one or more closely crowded series of dissepiments. Ex: *Acervularia, Diplophyllum, Lithostrotion.*
3. Stereoplasmic inner wall or *stereotheca*, formed by local thickening of the septa at corresponding points, by the

deposition of stereoplasm. Ex: *Prismatophyllum, Phillipsastræa, Pachyphyllum.*

4. Tabulate inner wall or *cyathotheca*, formed by the down-bending of the margins of the tabulæ, until they join the preceding tabula. Ex: *Depasophyllum, Diphyphyllum.*

In No. 1 the septa do not extend into the inner zone, in 2 and 3 they normally do extend into it, while in No. 4 they do not as a rule extend into it but may in exceptional cases do so. No. 1 is a true endotheca (holendotheca) Nos. 2 to 4 are pseudothecæ (pseudendothecæ).

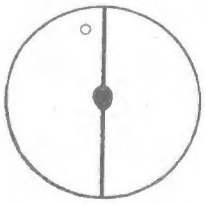

Fig. 31.

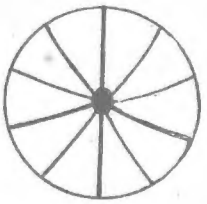

Fig. 32.

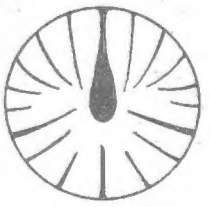

Fig. 33.

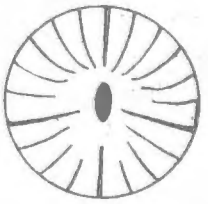

Fig. 34.

Figure 31-34. Diagrammatic sections of various types of corals to show the formation, by septal thickening of the pseudocolumella (stereocolumella). 31, *Cyathaxonia;* 32, *Lithostrotion;* 33, *Lophophyllum pendulum;* 34, *Lophophyllum proliferum.*

Columella and Pseudocolumella. A true columella is typically known only in the *Hexaseptata*, and forms an independent elevation which begins at the bottom of the thecarium and extends to the calyx, where it generally forms a styliform projection. This is seen in greatest perfection in *Turbinolia* (Eocene) and related forms. It may be simple or complex, a solid rod or a spongy structure composed of many sclerites, and represents the deposit formed in an original indentation of the central part of the base of the polyp. In the Tetraseptata, the columella, is not an original but a secondary structure being absent in the young. It may be formed by a thickening of the meeting points of the septa (*stereocolumella*), either the point of junction of the cardinal and counter septa as in *Cyathaxonia* (text fig. 31) or of all the longer septa as in *Lithostrotion* (text fig 32). Again it may be formed by the thickening of the end of the counter septum alone, as in the Dinantian species of *Lophophyllum* (text fig. 33 and Plate I, fig. 15b) or by the partial separation of the inner end of the counter septum with or without thickening (*palicolumella*) as in *Lophophyllum proliferum* (text fig. 34). These are the types commonly designated columellä in the Tetraseptata, and they project as central round or compressed rods from the bottoms of the calices. A structure more generally designated *pseudocolumella*, may be formed by the twisting of the inner ends of the septa, and the upward projection in the calyx, of these twisted structures (*streptocolumella*) as in *Streptelasma*, and *Clisiophyllum*. Another type of pseudocolumella is formed by the

deposition in the central portion at later stages in development, of irregular sclerites (*sclerocolumella*) as in *Enterolasma* (text fig. 35) or of stereoplasm (*stereocolumella*) as in *Stereolasma* (text fig. 36) and *Lopholasma* (text fig. 52 also Plate I, fig. 5b). Again such a structure may be produced by the more conical elevation, with or without twisting, of the tabulæ as in *Acrophyllum* (*acrocolumella*). This type, modified by the development of a central axis, is also found in typical *Lithostrotion*. A series of cysts may also form a more or less blister-like elevation in the center of the calyx as in some species of *Heliophyllum* and other types (*cystocolumella*). Finally there are complex types of columellas, formed by a combination of several of the structures described, as in *Lonsdaleia* and other genera. It is thus seen, that it is necessary to determine the type of columella in a given thecarium before this can be used in generic diagnosis.

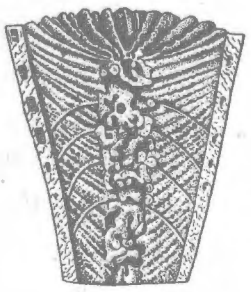

Fig. 35.

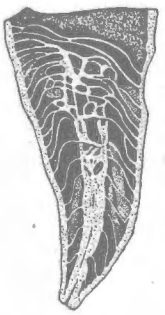

Fig. 36.

Figure 35. Longitudinal section of *Enterolasma strictum* (Hall) showing the *sclerocolumella* (after Simpson).

Figure 36. Longitudinal section of *Stereolasma rectum* (Hall), showing the *stercocolumella* (after Simpson).

Formation of Compound Coralla. In the Tetraseptata, so far as known, the formation of compound coralla is due to the development of new individuals from the parent corallite, by a process of budding. This is always calicinal, that is, the new buds arise from the margin of the parent polyp, and become distinct in the calyx of the hard structure as a marginal bud. Sometimes several or many such buds arise at the same time and their growth, together with that of the parent, may result in the formation of a compound corallum of numerous corallites in close juxtaposition, As they crowd one another, the soft-bodied polyps will assume polygonal outlines, and this will be expressed in the hard parts by the formation of closely placed calices of polygonal section. The continued growth of these polygonal individuals will result in the formation of prismatic corallites which may have their walls closely conjoined or even confluent, or the walls may remain sufficiently distinct to permit separation into individual prisms. If only a single bud forms at great intervals, this may develope into a lateral branch of the parent corallite as the latter grows in length beyond the point of formation of the bud. In that case a loosely fasciculate corallum will be produced, composed of more or less irregularly cylindrical corallites, not in contact, except now and then locally, when an epithecal connection may be effected, this strengthening the colony as a whole.

Fissiparous increase, or the development of new individuals by the division of the older, is not known to obtain in the Tetraseptata, though not uncommon in the Hexaseptata. Nor is intercalicinal budding found in the Tetraseptata, such as takes place

in some compound forms among the *Hexaseptata*, where new buds arise from the extrathecal portions of adjoining coralla (at the point of contact of the polyps). New colonies, or new individuals among the simple Tetraseptata are formed from ova, which develope independently of the parent.

Individual Development or Ontogeny. The individual development of the coral polyp is primarily controlled by heredity, though it may be modified by the environment to a certain extent. As the polyp developes, it records its successive morphic stages in the hard parts, which therefore, properly interpreted, give a complete picture of the ontogeny. This may be desciphered by successive sections across the corallum, for as a rule the earlier stages are but slightly, if at all, modified during the succeeding periods of growth and development. As the true understanding of the genetic relationships of the corals, as of other organisms, is possible only by a study of the ontogeny of individuals, the determination of the characters of the young and immature stages in development is of primal importance. The characters of the stages can generally be readily ascertained by the study of serial sections, and this is a necessary mode of proceedure to be followed in all coral study. Up to the present, only comparatively few types have been investigated in this respect, and hence much of our interpretation of genetic relationships, and indeed of generic and specific characters, based, as it is, wholly on adult characters, is inconclusive and provisional. Progress can only be made by the study of serial sections of the more distinctive species of each genus.

Acceleration and Retardation. In the development of individuals we may observe a variable rate in the formation of new characters. In the majority of individuals of a given species it is true, the rate is a fairly constant one, especially if the individuals are obtained from a certain locality. In some, however, or in members of the specific group from another locality, the rate of development may be more rapid, so that they will acquire adult characters at an earlier stage, and may even acquire characters not found in the normal members of the species. Such individuals are called accelerated (tachygenetic), and they may constitute distinct mutations, or they may even form distinct or accelerated species. In other cases the development is slower, and the individuals are retarded (bradygenetic). They may then, in their own adult stages, not pass beyond the more youthful features of the normal forms, and so produce retarded mutations or species. Acceleration and retardation may affect the entire individual, or may obtain in certain characters only, (unequal acceleration or retardation). Indeed a form may be accelerated (as compared with the normal) in some features and retarded in others. In this manner new genetic series may arise. Thus in one case a fossula may be developed while the septal arrangement remains in the primitive tetrameral stage, and

even carinæ may appear upon the septa thus retarded (*Pinnatophyllum scyphus*, and *P. scyphus* var. *carinata*). In other types from the same ancestral stock, the septa may develope beyond the tetrameral, into a radial stage, without the development of a fossula or of carinæ, (*Cyathophyllum*). In still another group carinæ may develope at an early stage, with radial septa, while a fossula does not develope or only in exceptional cases (*Heliophyllum*). It is thus seen that for a proper understanding of the individuals, the stage in development reached by each morphologic character must be ascertained.

Acceleration and retardation may be caused by the stimulating or retarding effect of the environment, or it may be the expression of normal inherited developmental vigor or lack of the same.

Intracolonial Acceleration and Retardation. As colonial forms are made up of many individuals, some of which may be endowed with more or with less developmental vigor than others, it not infrequently happens that some members of the colony develope beyond the normal while others are retarded, not reaching the normal stage in development attained by the average member. Thus in *Phillipsastræa*, while the normal individuals reach a stage in which the dividing walls are suppressed, the septa becoming exert, and those of adjoining corallites becoming confluent above the wall, there are not infrequently individual members of the colony, in which the walls are still retained. Thus there appear the characters of two species, if not of two genera, in the same colony. Again some colonies, which hold ancestral relations to *Phillipsastræa*, in which normally the dividing walls are present, may show accelerated individuals in which the wall has become suppressed by exert development of the septa. Again a colony of *Lithostrotion*, in which the columella (stereocolumella) is normally developed, may show retarded individuals in which the columella has not yet appeared, and which remain therefore in the ancestral Cyathophylloid stage (*vide. L. kaipingense*, Grabau).* Such a colony therefore combines individuals with the characters of two genera, a perfectly normal and possible condition, and one, indeed, which is to be expected. In all such cases, as for purposes of description and designation we must employ a single specific name for a colony (though in reality it may combine several species) the specific characters must be based on the stage in development reached by the average individual. A recognition of the principle of acceleration and retardation in colonial development, and its effect upon individual members of the colony, will lead to a proper understanding of these complex forms, and an avoidance of many pit-falls.

Retardation may also be due to injury or pathologic condition of certain parts of the colony, conditions which do not affect the main portion of the colony. Thus by the

* Described and figured in a subsequent fascicle.

suppression of some buds of a compact colony, the adjoining ones may develope without interference and therefore assume the normal cylindrical form, characteristic of the original parent corallite of the colony, before close crowding induces the formation of prismatic corallites. This is not uncommon in *Lithostrotion*, *Prismatophyllum*, etc., and indeed may occur in all prismatic colonies. Injury or weakening by environmental conditions may likewise produce retardation in other respects; more rarely it may act as a stimulus for over-rapid (precocious) development, the result being local acceleration.

In the succeeding discussion these principles will be applied wherever the nature of the case permits it, though in many cases only suggestions can be made regarding the relative stage in development reached by an individual, the final determination of which must await the investigation of the ontogeny of the type in question.

ORIENTATION. In the discussion of the genera and species the calices of the corals are oriented with the counter septum uppermost, and the cardinal septum below. The quadrants corresponding to the right and left hand respectively are referred to as right or left counter or cardinal quadrants, as the case may be.

SUBDIVISIONS OF THE TETRASEPTATA.

From the point of view of their development the Tetraseptata naturally fall into two great divisions or suborders, to which the names *Proteroseptata* and *Deuteroseptata* are here applied. The suborder of the *Proteroseptata* includes all those types in which septa appear before cysts or tabulæ, while the suborder of the *Deuteroseptata* includes those types in which the septa appear after the cysts or tabulæ, or sometimes do not appear at all or are only indicated by the arrangement of the cysts. *Streptelasma*, *Zaphrentis* and *Cyathophyllum* are characteristic genera of the *Proteroseptata*, while *Cystiphyllum*, *Chonophyllum* and *Strombodes* represent the *Deuteroseptata*. These suborders represent fundamental divergences in development, and can not be regarded as in any way closely related.

DESCRIPTION OF FAMILIES, GENERA AND SPECIES.

Suborder **Proteroseptata** Grabau

Family 1. **PETRAIIDÆ** de Koninck (emend. Grabau).

This family comprises simple corals of primitive structure, usually fixed by the base. Thecarium consisting of epitheca with simple septa in the form of longitudinal ridges but without dissepiments, columella, or tabulæ. The septa do not meet in the center, the calyx reaching to the bottom of the caliculum. In specialized types the septa may extend part-way to the center. The epitheca is thin, and shows exteriorly the septal grooves, in which the quadripartite arrangement of the septa is well shown. A certain amount of thickening of both septa and wall by stereoplasm may occur. All three orders of septa occur, the primary and secondary usually attaining to the same size, while the tertiary are shorter.

The corals of this family, which at present comprise the genera *Petraia* and *Polycœlia*, show in their adult stages the persistent primitive character through which the members of other families pass. They therefore present the characters demanded for ancestral forms by the majority of Proteroseptata, and it is reasonable to assume, that the earliest members of the genus *Petraia* represent the actual ancestors from which the more specialized types of the other families were derived. *Petraia* is said to range from the Ordovician to the Dinantian, but the Ordovician forms are still little known. Nevertheless it is among these that we must look for the ancestral types of the other *Proteroseptata*. The late Palæozoic species of *Petraia* can only be regarded as persistent primitive types, unless indeed some of them may prove on study of the very young stages, to be actually

degenerate forms, in which, by a process of retardation in development, the adult form remained in a very primitive stage.

No specimens of *Petraia* have so far been discovered in Chinese rocks.

The genus *Polycœlia* King of the Permian (Zechstein), apparently represents a further modification of this type in which the four primary septa have developed further, until they approach the center, while the secondary septa also have developed to a moderate degree. The quadrants in this genus are equally developed, there being five secondary septa in each. Other endothecal structures are absent.

Family 2. **STREPTELASMAIDÆ** Grabau (emend.)

Primitive to moderately specialized simple Tetraseptata, with the earliest stage, in primitive genera, often in the form of a non-septate tube, formed entirely of the epitheca. Primary septa appear before the secondaries in all but the most specialized types.

In the young of primitive forms, both primary and secondary septa appear as low ridges upon the inside of the thecarium, the calyx extending to the bottom of the caliculum. In more specialized types however, the septa meet at the center at a very early stage, thus restricting the depth of the cup. The quadripartite arrangement of the septa is retained in the immature stages of all genera, as well as in the mature stages of some primitive forms (*Streptelasma drofundum*). In most types however, this primitive quadripatite condition is replaced by a radial arrangement in the adult.

Tertiary septa are developed in all but the most primitive members of the family, appearing usually in a definite order, which corresponds to that of the secondary septa. In general they remain much shorter than the secondaries. Carinæ may be developed in some specialized types, and a fossula also appears in some of the Devonian genera. Tabulæ are as a rule wanting, except in certain specialized genera, but dissepiments occur, though they are never very numerous. They are, however, absent in the more primitive members of the family. No true columella is developed but a pseudocolumella may be formed, this taking on different character in the several branches. In some of the Ordovician types it is formed by the excessive growth in length, inwards, of the septa, which in consequence are forced to twist into a more or less solid central axis. This type of columella, especially characteristic of the genus *Streptelasma*, may be called a *streptocolumella* (*streptos* to twist). In some of the Silurian genera, the columella is formed by the interlacing of irregular prolongations from the inner ends of the septa, to form an

irregular structure which resembles in some respects the convolutions of the intestine (text fig. 35 p.23). This type of pseudocolumella may be designated a *sclerocolumella* and it is typified in the Silurian genus *Enterolasma* Simpson. In Devonian genera of this family the pseudocolumella is formed by the deposition of stereoplasm at the inner ends of the longer septa which thus form a more or less solid central axis. This type is illustrated by the genus *Stereolasma* Simpson, and is designated a *stereocolumella*, (text fig 36, p.23). Finally in the Carbonic members of the family, the pseudocolumella is formed by the partial separation (in the adult) of the inner end of one of the four primary septa (typically the counter septum), this separated end being more or less thickened by secondary deposits of stereoplasm. In some forms this inner end of the counter septum may be thus thickened without actual separation from the septum (text fig. 33, p.22). This type of columella is designated a *palicolumella* and is well illustrated in *Lophophyllum proliferum* (text fig. 34, p.22). Externally the septal grooves always show the tetrameral arrangement of the septa in well-preserved specimens.

The primitive members of this family all belong to the genus *Streptelasma*, and are represented by such types as *Streptelasma profundum* of the late Middle and early Upper Ordovician of America. This species appears indeed to be the fundamental form from which the other members of the family are derived. That *Streptelasma* itself is a derivative from an early member of the *Petraiidæ*, seems to be indicated by the similarity of the young *Streptelasma* of the *S. profundum* type, to adult *Petraia*, this similarity being expressed by the short ridge-like septa, the absence of all dissepimental and other endothecal structures, and the deep calyx which extends to the bottom of the caliculum. The fact that a still earlier stage in *S. profundum* shows only an empty epithecal tube without septa, indicates that its distal ancestry is from still more primitive aseptate types, from which the known *Aseptata* have also been derived.* So far as our present knowledge permits us to judge, all the other families of the *Proteroseptata* are derived either directly or indirectly from the *Streptelasmaidæ* with the probable exception of the *Palæocyclidæ* which may have originated independently from the *Petraiidæ*.

The following genera are at present included in the family *Streptelasmaidæ*. Those so far recognized in Chinese formations are preceded by an asterisk*.

1. *Streptelasma Hall.* Ordovician
2. *Enterolasma* Simpson Silurian
3. *Helenterophyllum* Grabau Silurian
4. *Kunthia* Schlüter Devonian

* Sec T. C. Brown 1918, Development of some Palæozoic corals.

* 5. *Stereolasma* Simpson Devonian
* 6. *Lopholasma* Simpson Devonian—Carboniferous
7. *Ditoecholasma* Simpson Devonian
8. *Kionelasma* Simpson Devonian
* 9. *Amplexus* Sowerby, Dev. to Dinantian
* 10. *Tachylasma* Grabau Carboniferous
11. *Heterolasma* Grabau Dinantian-Carb.
* 12. *Lophophyllum* Edw. & Haime Dinantian to Carbonic
* 13. *Arachnolasma* Grabau Dinant.-Carb?

The following genera are doubtfully placed here:

Kanophyllum Dybowsky Ord-Sil.
Duncanella Nicholson, Silurian
Metriophyllum E. & H. Devonian

Genus **STEREOLASMA** Simpson.

Text figures 36 - 49.

The genus *Stereolasma* was separated from *Streptelasma* Hall, by Simpson (1900, p.205) on the character of the pseudocolumella, which in this genus is formed by a deposit of stereoplasma about the inner ends of the septa (*stereocolumella*) (text fig. 36, p.23) whereas in *Streptelasma*, it is formed, when present at all, by the twisting of the inner ends of the septa. This deposit of stereoplasm is however not an unusual feature in Palæozoic corals, and it might be questioned if generic separation on this basis alone were warrantable. There is however another feature in this genus, the significance of which did not escape the keen powers of observation of Simpson, though he did not emphasize it as strongly as he might have done. This is the development of a fossula by the abortion of the cardinal septum, a feature which gives the coral somewhat the aspect of a *Zaphrentis*. It is indeed with the latter genus that Simpson compares this coral, giving as its chief distinction from it, the pseudocolumella.

There is, however, no direct genetic relationship between this genus and *Zaphrentis*, the two genera belonging indeed to distinct families. The development of the fossula, which gives this coral a zaphrentoid appearance, is a feature independently arrived at in the two families as previously noted. In Zaphrentis and its congeners, this feature is developed at a very early period, in the Streptelasmaidæ it appear only in such specialized late Palæozoic genera as *Stereolasma* and *Lophophyllum*.

A further point of distinction between *Stereolasma* and *Zaphrentis*, is the accelerated condition of the counter quadrants in *Stereolasma*, these always having a greater number of septa than do the cardinal quadrants. In *Zaphrentis*, on the other hand, the cardinal quadrants are generally accelerated, except in the more primitive forms, in which the quadrants are equal, as they are in the primitive Streptelasmaidæ (*i.e. Streptelasma* itself). There is thus indicated a fundamental divergence in development of the two types. Absence of tabulæ can not be considered a distinctive feature, for in primitive *Zaphrentis* these are also absent.

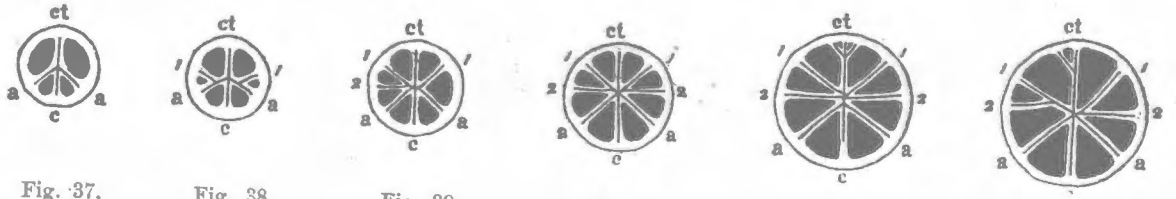

Fig. 37. Fig. 38. Fig. 39. Fig. 40. Fig. 40a. Fig. 41.

Figures 37-41. Early stages of *Stereolasma rectum* (Hall) as shown by seve.al sections of the same individual caliculum, except figures 37 and 40a which are from other individuals (enlarged); c - cardinal septum; ct - counter septum; a,a - alar septa; numbers indicate order of appearance of secondary septa. (After T. C. Brown).

In the earliest stages of primitive species of *Streptelasma*, such as *S. profundum* of the Ordovician, the caliculum consists merely of an epithecal tube, this being followed by the appearance of the four primary septa, and shortly thereafter, by the secondary septa in rapid succession. This is the *Petraia* stage in development (Brown 1909). It is only in the adult that the septa meet in the center while retaining the characteristic quadripartite arrangement. In *Stereolasma*, on the other hand, the initial non-septate epithecal tube is

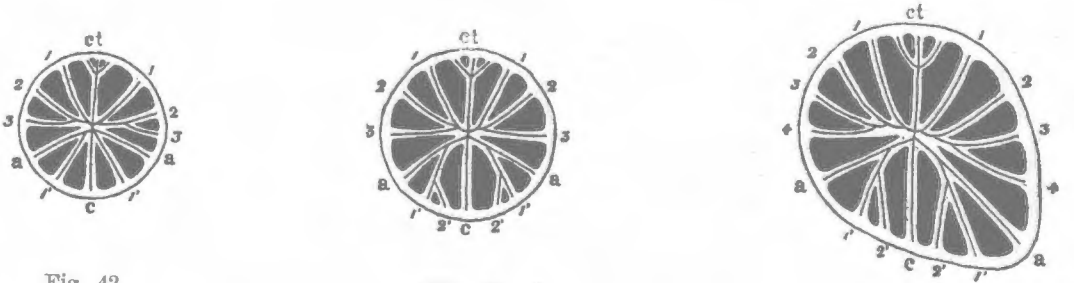

Fig. 42. Fig. 43. Fig. 44.

Figures 42-44. Three further stages in the development of the caliculum of *Stereolasma rectum* shown in the preceding series. Tertiary septa are well developed on either side of the counter septum (ct). (After T. C. Brown).

no longer formed, the primary septa appearing at the earliest observable stage, (text fig. 37) (Brown 1907). Thus this type is strongly accelerated in development, when compared with the primitive members of its family. The septa, throughout a considerable period of development, indeed through the neanic stage, retain the primitive quadripartite arrangement, being clustered into four groups with the alar pseudofossula well developed, (text

figs. 42-46). During this period of their development, they are therefore in the *Streptelasma profundum* stage. With the attainment of adulthood, however, the septa become radial in arrangement, except for the coalescence, in the center, of their inner ends. It is at this stage that the fossula is developed by the abortion of the cardinal septum.

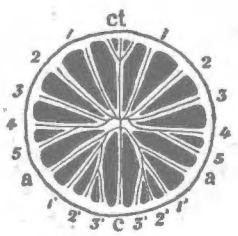

Fig 45.

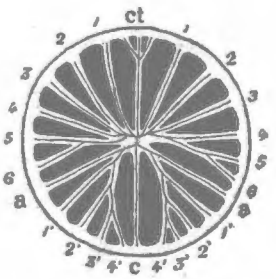

Fig. 46.

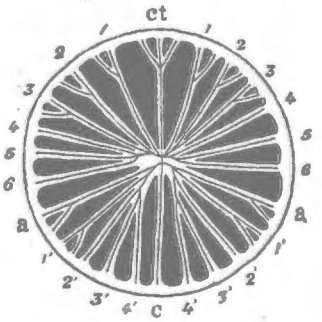

Fig. 47.

Figures 45-47. Three further sections of the caliculum of *Stereolasma rectum* showing the increase in number of secondary septa and the appearance of tertiary septa in figure 47. The accelerated condition of the counter quadrants is well shown. In figures 45 and 46 the alar and cardinal pseudofossulæ are seen. (After T. C. Brown).

The dissepiments are generally few, and formed chiefly in the later stages. They are often convex inward, and then have the value of incipient tabulæ or cysts. The number of dissepiments in the interseptal spaces is in most cases few, sometimes only one being present in a given section.

GENOTYPE. *S. rectum* (Hall) Middle Devonian.

Stereolasma rectum (Hall.)

Plate I, figs. 1a, b. Text figures 37-49.

1876 *Streptelasma rectum* Hall, (in part) Illustrations of Devonian Fossils pl. 19.

1899 *Streptelasma rectum* Grabau, Pal. Eighteen Mile Creek. p. 127. fig. 9.

1900 *Stereolasma rectum* Simpson, New Genera of Palæozoic Rugose Corals. p. 205, figs. 16 & 17.

1907 *Streptelasma rectum* Brown, Am. Journ. Sci. Vol. XXIII, p. 277 figs. 1-13.

1909 *Streptelasma* (*Stereolasma*) *rectum* Grabau and Shimer, North American Index Fossils Vol. I. p. 56, Figs. 78, 79.

Corallum small, generally slightly curved, and expanding at a variable rate in the young, which gives the individual an irregular lower portion, marked by frequent constrictions which are generally restricted to a part of the circumference, though not always

to the same portion. Upper part expanding more regularly, and essentially circular in section. As only a single individual is known from Chinese rocks, this basal irregularity may not be normal. In typical individuals from the Hamilton group of New York state, the form is more regular, and the expansion more uniform, but equally irregular forms may be found. The coarsely wrinkled character of the epitheca, caused by the irregular and frequent constrictions, is also found in specimens of this species in the Traverse group (Middle Devonian) of Michigan. Between the coarser wrinkles, the epitheca shows crowded, rather regular, fine growth lines. The septal grooves are well shown, permitting ready determination of the location of the primary septa.

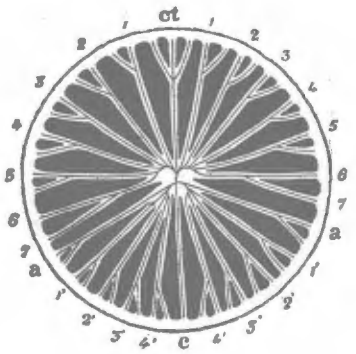

Fig. 48.

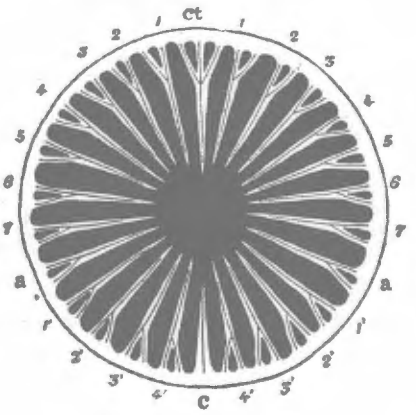

Fig. 49.

Figures 48-49. The submature and mature stages of *Stereolasma rectum*, with tertiary septa well developed. In figure 49 the septa are seen to have assumed a radial character, and the cardinal septum (c) has become somewhat shortened, showing the beginning of the fossula. (After T. C. Brown).

Septa more or less radially arranged in the adult. Fossula not pronounced. Septa of counter quadrants mostly reaching the center. The septa are all somewhat irregular near the center, but no twisting occurs. There is practically no deposit of stereoplasm on the septa, but the inside of the epitheca is slightly thickened by it. Dissepiments rather well developed. Tertiary septa of moderate length, longer in cardinal than in counter quadrants. Length of the specimen described about 28 mm.; diameter at calyx 19.5 mm.; at section, 16. mm.

Horizon and Localities. A single specimen only, has so far been obtained from the Mid-Devonian beds of Tungshan, Kütsing district, Yunnan, where it was collected by Dr. V. K. Ting, The specimen is overgrown by a species of *Hederella*. In the State of New York (U. S .A.) this species is probably the most abundant and most characteristic coral in the Middle Devonian Hamilton shales. In aspect the Chinese specimen is quite similar to many individuals from New York State though the dissepiments are more abundant than usual. The species has also been obtained from the upper Hamilton

(upper Traverse) beds of Michigan, occuring both on the east, at Alpena, and the west near Petoskey. It has also been reported from the Cedar Valley limestone of Iowa and the Devonian beds of the Mackenzie River, ten miles below the mouth of Bear River. This clearly indicates that the path of migration of this organism, between eastern North America (New York) and China, was by way of the north-west channel or Dakota Sea, and the Alaskan region* to northwestern Asia. But the path of migration thence to southern China is not yet apparent, since no Devonian formations are known from northern China. The species is wholly unknown in Europe.

It is most likely, that this species originated in the New York basin from some earlier Devonian or late Silurian ancestor, though this type is as yet unknown. The great abundance of the species in eastern North America suggest that this was the center of distribution. It is a remarkable fact that the Chinese form is so little modified that it can hardly be regarded as a variety of the typical form of the species.**

Genus **TACHYLASMA** Grabau (gen. nov.)

Corallum streptelasmoid, regularly expanding, or with slight constrictions at intervals; epitheca thin with septal grooves well marked, and showing the tetrameral arrangement. Septa subradial, all more or less thickened by stereoplasmic deposits for the greater part of their length. The alar septa and the first pair of secondary septa on either side of the counter septum most prominent. Cardinal septum more or less aborted to form a fossula. Dissepimental tissue not well developed.

The essential characters of this genus are its streptelasmoid form and the strong development, by stereoplasmic thickening, of four of the septa. These are the two alar, and the first pair of secondary septa in the counter quadrants, the counter septum itself being less prominent. Other septa are also thickened in some species. This indicates extreme acceleration in certain directions, *i.e.* in the septal development, and this is expressed in the generic name.

That this type is a derivative from the more specialized streptelasmoids, possibly from *Stereolasma*, is suggested by its general form and structure, and by the septal development. In *Stereolasma* the first pair of secondary septa appears in the counter

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Fig. 1292 * See the Palæogeographic Map of Hamilton time in A. W. Grabau, Textbook of Geology, Vol. II. p. 407

** The collection of which this specimen was a part had been sent to the United States for identification and has just been returned. It is barely possible, though highly improbable, that the coral described above, is an American form which has inadvertently been included in the collection. If so it is the only American form thus included. Further collecting in the Chinese rocks will have to settle this point. Dr. Ting identified the specimen as one collected by him.

quadrants shortly after the appearance of the four primary septa (See text figs. 38 *et seq.* p. 31). In another member of the Streptelasmaidæ, the genus *Lophophyllum*, this first pair of secondary septa of the counter quadrants appears so early (by acceleration) that, as shown by Duerden, it is already present in the earliest obtainable sections. The present genus shows further acceleration in the thickening of these two secondary septa beyond that which occurs in the counter septum. In this respect therefore the counter septum is retarded.

Unfortunately we have not enough material to permit the making of serial sections from which the progress of septal development might be ascertained, but there seems no reason to suppose that it was other than that known in *Stereolasma rectum*.

GENOTYPE. *Tachylasma cha* Grabau, Carbonic.

This genus differs from *Pentaphyllum* de Koninck, primarily in the septal development. In that genus there are five pronounced septa, the counter septum and the two alar septa, and in addition two septa bordering the cardinal region. Sometimes the cardinal septum too is strongly developed, at other times it is aborted to form a fossula. In that genus too, the quadrants are equally developed, or the cardinal quadrants are slightly accelerated, as shown by an excess of secondary septa, as well as the strong development of the cardino-lateral septa. This allies that genus with the Zaphrentidæ in which family de Koninck placed it.

Tachylasma cha Grabau (sp. nov.)

Plate I, Figs. 2a, b. Text fig. 50.

Corallum attached basally, and closely resembling *Stereolasma rectum* for which it might be mistaken from external appearance alone. Moderately curved, more so in the young than in the adult, with the counter septum on the side of greatest curvature. The corallum expands at a rather regular rate, though there are a number of irregular but not very pronounced constrictions which give the surface a moderate rugosity. Epitheca thin, the septal grooves and interseptal ridges pronounced as in *Streptelasma*, the quadripartite arrangement being well shown. Growth-lines not prominent, except at irregular intervals. Septal arrangement distinctly quadripartite, the counter quadrants being the most accelerated. Counter septum reaching to within a short distance of the center, moderately thickened by deposits of stereoplasm on each side, the greatest thickening being in the inner third of its length. It is flanked on either side by a very short tertiary septum

radially disposed. Beyond this on either side are the secondary septa of the first pair. These are radially disposed, longer than the counter septum, and much more strongly thickened than it. Their section resembles a willow leaf, with the original septum forming the mid-rib. Where the diameter of the calyx is 13.5 mm., the greatest thickness of the septum is 1 mm, while that of the counter septum is only about 0.5 mm. The next septum of this quadrant (the second secondary) is much shorter, the third is still shorter, being about half as long as the first, while the fourth is longer than the second but does not attain the length of the first. The relative lengths of the first four septa of this quadrant are as 5, 3, 2.5, 4. The fifth and sixth secondary septa are nearly as long as the fourth, each being a trifle less than the preceding, while the seventh and eighth are much shorter, the seventh being about half, and the eighth about one fourth as long, as the fourth secondary septum. Between all the secondary septa are very short tertiary septa, such an one also occurring between the last of the secondary (8th) and the alar septum. All the later secondary septa bend slightly towards the first one, and they are moderately thickened by stereoplasm. The alar septa are prominent, in length and thickness resembling the first pair of secondary septa of the counter quadrants, one indeed being even more thickened than these (nearly 1.5 mm).

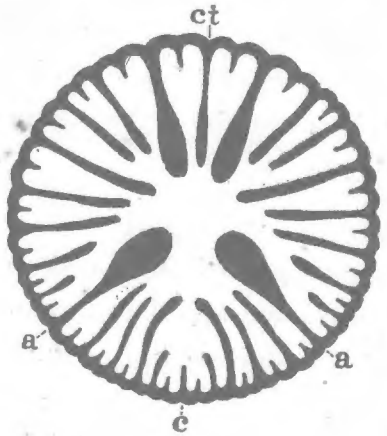

Fig. 50.

Figure 50. Semidiagrammatic section of *Tachylasma cha* Grabau near the calyx, showing the thickened alar septa (a,a) and first pair of secondaries in the counter quadrants; the nature and relative lengths of the other septa and the formation of the fossula by abortion of the cardinal septum (c).

The first three pair of secondary septa in the cardinal quadrants are of moderate strength the first two averaging about two thirds the length of the alar, and moderately thickened, while the third is longer than the preceding and more strongly thickened. All are separated by short tertiary septa. The third septum bends towards the cardinal septum, nearly embracing the area in which this is situated (fossular area). There are, however, two shorter secondary septa within this area on each side of the cardinal septum. The latter is aborted to form the fossula. (Text fig. 50).

There are then, five secondary septa in each cardinal quadrant and 8 in each counter, showing the extreme tachygenetic character of the counter quadrants, this being also expressed by the strong development of their first pair of secondary septa.

Dissepiments are very sparingly developed, and the epitheca is only moderately thicked by stereoplasm. The central area appears to be free from endothecal tissue, none of the septa reaching it. In this respect the corallum appears to be somewhat retarded.

The most striking feature of the coral is the septal arrangement and especially the four strong septa (two alar and first pair of counter secondaries). They apparently project above the others in the calyx being exert, though, because of the crushed character of the calyx in the only known specimen, this could not be ascertained with certainly. Their appearance in section resembles rather closely the Chinese ideograph for fork which is *Ch'a* (叉) (pronounced *Cha*), and this has suggested the specific name.

Length of the holotype exclusive of calicinal portion, 19 mm.; original length about 22 mm. Diameter of calyx about 16 mm., at section 13.5 mm.

Horizon and Locality. The holotype and only known specimen was associated in the collection with two specimens of *Lophophyllum* and has moreover attached to its base two slender spines of a *Productus*. Thus its Carbonic age seems to be established. Unfortunately in the transit of these specimens to America, their travels in that country, and their final return to China, the label was lost, and the locality is therefore unknown. There is reason for believing however, that the specimen came from South China, possibly from Yunnan.

Tachylasma elongata Grabau (sp. nov.)

Plate I, figs. 13 a-c.

Corallum curved in the lower part, moderately expanding, becoming turbinate cylindrical in the adult, and contracting slightly in the final portion. Surface characterized by rather strong and numerous concentric wrinkles, and by well-marked septal grooves and interseptal ridges. In the holotype, the cardinal septum is not on the side of greatest curvature, one of the alar septa very nearly occupying this position.

At the section across the lower end, where the diameter is 6 mm. (pl. I, fig. 13c) the alar septa are most strongly developed, the first pair of counter secondaries coming next. These four septa are much thicker and longer than the others, but do not reach the center. The counter septum is slender and only about two-thirds as long as the first pair of secondaries adjoining it. There are four additional secondaries in each counter quadrant those on the left (right in figure) being best shown. Thus there are five secondary septa in each counter quadrant at this stage, the first very strong and large, the second less than half its length, the third and fourth each somewhat longer than the preceding but not reaching the length of the first; and the fifth again short.

The cardinal septum is about half as long as the alar and there are three secondary septa of similar length on either side, those nearest the alar septa being shortest. Tertiary septa are faintly developed at this stage, but no dissepiments occur.

At the other end of the fragment, which is 35 mm. long, the section, which here is only a short distance below the calyx, has the appearance shown in fig. 13b. plate I. The alar septa are strongly thickened and club-shaped, while the first pair of counter secondaries is similar, but the thickening less in amount. They are also of unequal length. The counter septum between them is narrow, slender and about half the length of the longer secondaries. There are six additional secondaries in each counter quadrant. The second is less than half the length of the first, the third and fourth are progressively longer, and the last three again somewhat shorter and slightly unequal.

The cardinal septum is short, producing a marked fossula. The three secondaries adjoining it (2 to 4th) are strong and approximately equal, while the one next to the alar is much shorter.

There are thus four secondaries in the cardinal and seven in the counter quadrants. Tertiary septa are developed as mere spinous projections, and dissepiments are absent.

This species is thus somewhat less advanced in septal development than is *Tachylasma cha*, but the length of the corallum is nearly three times that of the preceding species though its calicinal diameter is about the same.

Horizon and Locality. In the Lower (?) Carboniferous limestone of Fengchen in Kiangsi province. One specimen.

Tachylasma aster Grabau (sp. nov.)

Plate I, Figs. 3a, b, 4. Text fig 51.

Corallum more slender than that of *Tachylasma cha*, tapering at a much less rapid angle but shorter than *Tachylasma elongata*. Calyx unknown, but principal thickened septa probably more or less exert.

The largest section obtained is circular, with a diameter of 12 mm. The counter, alar, and several of the secondary septa are thickened inwards until they have a club-shaped section. These thickened septa meet in the center and join into a larger stereoplasmic body, from which the tapering ends of the septa radiate like rays from the central part of a star. On the cardinal side this central mass is marked by a long narrow

slit which reaches beyond the center and is bottle-shaped in section with a narrow neck. Through this neck a slender thread-like prolongation of the cardinal septum enters the flask-shaped slit. The outer half of the cardinal septum is thicker, but it is still the thinnest of all the septa.

The alar septa are the most strongly thickened, the first pair of secondaries in the counter quadrants coming next, though the counter septum is almost as much thickened as they are. As will be seen later this is not the case at an earlier stage. In the left counter quadrant, the third fourth fifth and sixth secondary septa are only slightly less thickened, forming a part of the central asteroid column. The second and seventh are shorter and do not joint the central column. In the right counter quadrant, only the fourth and fifth secondary septa are sufficiently thickened and lengthened to form a part of the central mass, but the third and sixth are not far behind in this respect.

The second and third secondary septa of the cardinal quadrants are also thickened, and join the central mass, while the first and fourth are shorter and free.

Short tertiary septa occur in all the interspaces. In some cases these are joined at their inner ends to the secondaries. On either side of the cardinal septum occurs a tertiary one which curves towards it. A few dissepiments occur between the secondary septa.

A section of this same individual, four millimeters farther down, on the other side of the rock slice, is shown in fig. 3b Pl. I, (reversed). It is 9.5 mm. in diameter, giving a rate of tapering of 1 in 1.6 mm. The alar and the two principal secondaries of the counter quadrants are the strongest of the septa. The counter septum is much weaker, but its thickened end fills the space between the other two. In the left counter quadrant (right in figure) the third fourth and fifth secondary septa join the central body; they are however less thickened than the first. The sixth, which in the section four millimeters higher, also joins the central body, is here free, though thickened, and tied to the alar septum by a dissepiment. The seventh, well developed in the higher section, has not yet appeared. On the right (left in figure) the second and third septa of the counter quadrants are free, the fourth and fifth joined to the median body, while the sixth is short and free. The seventh, also well developed in the higher section, has not yet appeared.

The cardinal quadrants have their septa only slightly less developed than in the higher section. The first in each case is free. The second and third on the left (right in the figure) join the central mass, on the right (left in view), they are still, in part at least, distinct, though joined together and meeting the counter septum. The fourth on each side is shorter and bends to the cardinal which is long but slender, becoming more

attenuated towards the center where it meets the central mass. The tertiary septa are for the most part still buried in the stereoplasmic thickening, especially in the cardinal quadrants. In the counter quadrants they become free.

A section about 2 mm. lower (diameter 8 mm.) shows a nearly complete filling in of the endothecal area by stereoplasm, only a few loculi remaining near the periphery.

An earlier stage of another individual from the same rock as the preceding, (Pl. I, fig. 4), also shows a subcircular section about 8.5 mm in diameter. The alar septa, and the first septum of each counter quadrant, are thickened to club-shaped form, meeting and joining in the center of the corallum by their thickened ends. The counter septum is also thickened but less so than the others, with which it becomes confluent at the thickened end. Two other septa *i.e.* the fourth septum in each counter quadrant, are long and somewhat thickened uniformly, meeting the others at their inner ends. The second and third are shorter and radially disposed, those of the right quadrant being longer than those of the left. In the right counter quadrant, septa 5, 6, & 7 are radial, stop short of the center, and decrease in size progressively towards the alar septum. On the left, the corresponding septa are much shorter, the 7th being hardly separated from the alar septum close to which it lies.

The cardinal septum is thin and long, slightly curved, and enters the triangular central space between the thickened ends of the alar septa. There are four radially disposed septa in each quadrant, two central ones long, their relative proportion different in the two quadrants, and two short, one on either side of the longer ones. Heavy dissepiments unite some of the septa at or near their inner ends.

The epitheca is greatly thickened on the inside by stereoplasm, the innermost layer of which is continuous with that of the septa. Within this thickened wall of stereoplasm, which is in this section a millimeter or more in thickness, are seen short tertiary septa which do not enter the interseptal cavities. Septal grooves very slightly developed.

The stage here described approaches closely the adult stage of *Tachylasma cha*, but is still more accelerated than that, although the section is that of a much younger individual.

A section about 4 mm. lower down, (diameter 6 mm.) shows solid filling of stereoplasm between the septa, except on either side of the cardinal septum, where slight lacunæ remain. The alar and first counter secondaries unite on either side, completely cutting off the septa between them from the rest of the corallum. In this area are four or

five shorter septa. The counter septum is long, extending to the center, and the same is true of the cardinal septum. Individual thickening of septa is not apparent, but the filling between them is rather uniform.

A section about 2 mm. lower, (diameter 4mm. text fig. 51) shows the four primary and the first pair of counter secondaries meeting in the center. The alar are the strongest while the others are about alike and somewhat less strongly developed. Three additional shorter septa occur in each counter quadrant making four in all, while only two occur in the cardinal quadrants. The interspaces are filled with lime carbonate.

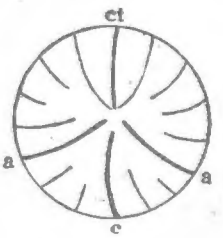

Fig. 51

Figure 51. *Tachylasma aster* Grabau. Arrangement of the septa in the early portion of a caliculum. (Enlarged).

HORIZON AND LOCALITY: This species was obtained by Messrs. C. C. Liu and C. Chao from dark limestones in the coal series of Changhsing Coal Mine, province of Chekiang. Two individuals are associated in the same rock fragment. The age of these beds is probably Permian.

Genus **HETERELASMA** Grabau (gen. nov.)

Plate I, figs. 14a, b.

(Genotype: *Hadrophyllum edwardsianum* de Koninck, Nouvelle recherches, 1872, p. 52, pl. IV, figs. 2, 2a.)

Corallum small, simple, gradually expanding, the basal portion moderately curved. Epitheca thin with the septal grooves well marked, showing the primitive pinnate arrangement, with the cardinal groove on the convex side. Calyx deep, with the septa in the primitive grouping in four series, their inner ends uniting, and still exhibiting the four pseudo-fossulæ, one on either side of the cardinal septum, which is fully developed, and one next to each alar septum. In this respect then the coral has the characters of *Streptelasma profundum*, and as it is a late Palæozoic type, this persistence of primitive ancestral characters indicates retardation in development. In two other respects, however, the coral is more specialized, or accelerated. In the first place the counter quadrants are accelerated as in all but the primitive *Streptelaspàidæ*. While the number of secondary septa in the cardinal quadrants is from 5 to 6, that in the counter quadrants is from 7 to 10. In the second place acceleration is shown by the partial abortion of the counter septum, thus producing a true counter fossula, a feature not found in any other

member of the family *Streptelasmaidæ*, and representing a degree of acceleration beyond that usually found in these corals.

The genotype *Heterelasma edwardsianum* (de Koninck) Grabau, the only species so far known, occurs in the Carboniferous limestone (Dinantian) of Tournai, Belgium.

Genus **LOPHOLASMA** Simpson.

(Bull N. Y. State Mus. No. 39, 1900, p. 206).

Text figs. 52, 53.

This genus was created by Simpson for a Devonian species (*S. carinatum* Simpson) which in its external characters resembles closely the common *Stereolasma rectum* of the Hamilton group of western New York, (U. S. A.) with which it is associated. The corallum is conical, straight or slightly curved; the epitheca is marked by wrinkles of growth and numerous growth-lines, but shows distinctly the septal grooves. Septa alternating in size, the larger extending to the center, where there is a deposit of stereoplasm forming a pseudocolumella (stereocolumella), which does not rise above the bottom of the calyx. Sides of septa characterized by strong, essentially horizontal carinæ which extend from the exterior wall to the extremity of the septum (See text fig. 52). In transverse section, curved, spur-like processes are seen proceeding from the sides of the septa. Tabulæ, if present, delicate; dissepiments frequent.

Simpson states that the nature of the spur-like spines has not been ascertained. They appear to be common features in the Carbonic Streptelasmaidæ of China for they occur in several species of *Lophophyllum* as well as in this genus. They have the appearance of cross-sections of branch septa, growing out from the main septum and not infrequently they are found to extend continuously to the margin if they begin as outward pointing spines, or they extend to the center as supplementary septa if pointing inward at the beginning. It is however still uncertain whether these spines are really always sections of plate-like branches of the septa. As shown by sections of *Lophophyllum acanthiseptum* Grabau (*postea*) similar spine-like processes occur where the carinæ are cut obliquely. Again where an upturned edge of the carina is cut by the section, the appearance of a branch septum is produced. A series of sections of calicula of the type species, *L. carinatum*, or an unusually well-preserved individual, is needed, to fully solve this problem. The species described below carries this genus into the Carbonic. The Devonian form is probably derived from *Stereolasma rectum*.

KNOWN RANGE: Devonian to Lower Carboniferous.

Lopholasma carbonaria Grabau (sp. nov.)

Plate I, Figs. 5a, b; 7d, 8d, 9d, 10d, 11d, and 12. Text figures 54-56.

Corallum small and generally more gently tapering than in *L. carinatum*. The specimen fig. 5, has a length of 23 mm. and its diameter is 9.5 mm. Apical portion bent nearly at right angles but the greater part of the caliculum straight, or else the whole corallum irregularly curved. Epitheca thin, with frequent not very pronounced growth wrinkles and faint growth-lines. Setal grooves marked, especially in the young, more or less obscure in the adult; inter-septal ridges somewhat angulated along the center. Section circular. There are slight, irregularly disposed, nodes, suggestive of the bases of rhizoid proliferations. Septa radial, except those on either side of the fossula, which converge slightly at their inner ends. Fossula narrow, with the cardinal septum very short. There are about 10 septa on each side of the median axis, many of them appearing double where the section cuts the margins of the carinæ (Plate I, fig. 5b). In a few cases they even appear to be triple. In a number of cases, spine-like processes project from the central area about half-way towards the periphery. All of these appearances are probably due to the fact, that the upturned margins of the carinæ have been sectioned. The central portion of the corallum is occupied by a mass of stereoplasm which connects the inner ends of the septa, and occupies about two fifths of the endothecal area. It forms an irregular pseudocolumella. The outer wall is also strongly thickened by stereoplasm, but the septa only slightly so. Their chief modification lies in the development of the septal carinæ, which are more or less horizontally disposed. These carinæ have their outer margins upturned, and when a section is nearly paralled to the carina, this sectioned upturned margin appears like a delicate branch septum. When the section is oblique to the carina, the appearance of a spine is produced, the length of which is proportional to the nearness of the section to parallelism with the carina. Dissepiments are fairly numerous, thin and for the most part cystiform, *i.e.* convex inwards.

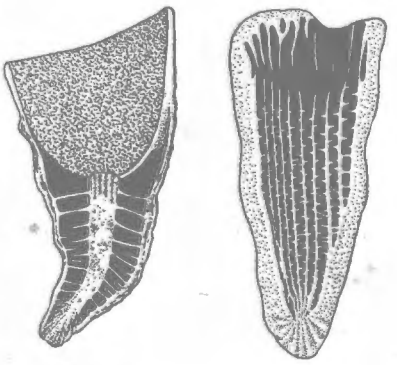

Fig. 52. Fig. 53.

Figures 52-53. *Lopholasma carinatum* Simpson. Middle Devonian, New York (U. S. A.) (After Simpson enlarged).

52. Longitudinal section showing depth of calyx, pseudocolumella, and the edges of horizontal septal carinæ. (compare text figure 65).

53. Longitudinal section near the margin, showing the edges of the septa and the width of the carinæ (compare Plate I, fig. 18c).

A series of sections of a typical individual from Shantung, embedded in rock, shows the gradual modifications during the progress of development. (Plate I, figs. 7-11 specimen *d*; the sections are cut obliquely). The cardinal septum is less thickened by

stereoplasm than the others. In a section 6 mm. in minimum diameter* (Pl. I, fig. 8d, text fig. 54) the septa are all united by stereoplasm, and much thickened. Some of the septa divide near the periphery or have slender septa joining them, this appearance being due to the carinæ. Between the septa are cystose dissepiments, *i.e.* with their convexity inward, these probably being also in many cases sections of carniæ. Spines are shown on the opposite side of the same rock slice (Pl. I, fig. 9d, text fig. 55) which is 3 mm. thick. Here the minimum diameter is 8 mm. The dissepiments have practically disappeared, having been broken up into the spines, which appear to be the remnants thereof. The cardinal septum is thin but still reaches to the center, where the stereocolumella is still strong. The secondary septa of the cardinal quadrants are still united at their inner ends, as are also some of the later ones of the left counter quadrant. Some of the others however have begun to separate into groups, which are only slightly united at their inner ends. This appearance is chiefly due to the fact, that they are cut at a higher level than those of the cardinal quadrants, because of the obliquity of the section. It should be noted that in the higher part of the section (*i.e.* in the counter quadrants) only spines occur, while in the lower part (cardinal quadrants) the dissepiments still persist to some extent. The tertiary septa join the secondaries in most cases, that is, they are continuous with spinous processes from the secondaries, these processes remaining as such when the tertiaries become free. Another section, about 2 mm, higher (Pl. I, fig. 10d reversed, text fig. 56) shows three of the septa of the right counter quadrant (left in figure) with free inner ends, but still united by inward convex dissepiments. The others are united centrally, those of the cardinal group forming a narrow horse-shoe-shaped wall around the fossula in which the cardinal septum has only a very slight development. Many of the dissepiments of the cardinal quadrants are now broken up into spines. Judging from the relationship of the septa, there are two secondary ones in the left (right in the figure) and 3 (the third a small one) in the right (left in figure) cardinal quadrants, those of each group are joined together and to the corresponding alar septum. There are six septa in each of the counter quadrants, while

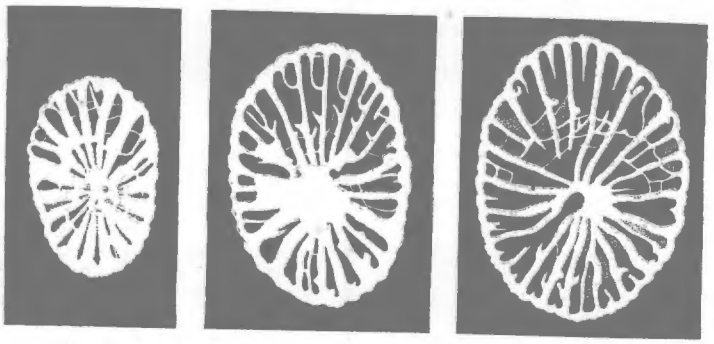

Fig. 54. Fig. 55. Fig. 56.

Figures 54-56. *Lopholasma carbonaria* Grabau. Three successive sections (somewhat oblique) of the specimen shown in Plate I, figs. 8d, 9d, and 10d respectively, enlarged. (Figs. 54, and 56 are reversed, 55 in normal orientation).

* Minimum diameters are given, because, since the sections are oblique, these represent more nearly the true diameter of the circular sections.

the counter septum itself is thin. In the next section on the opposite side of the slab, Pl. I, fig. 11d (about 2.5 mm. higher, minimum diameter 10.5 mm.) the septa of the cardinal and some of those of the counter quadrants as well, are free, but the others are still united. The dissepiments are still present in some cases, but very thin. There are no spines but some of the tertiaries are still joined to the secondaries. In the last section finally, about 2 mm. higher, minimum diameter 11 mm. (Pl. I, fig. 12, reversed), the septa are all free at their inner ends, and the pseudocolumella has disappeared. Additional stereoplasm has, however, developed in the left cardinal quadrant (right in figure) which ties together the septa at their inner portions, where in the previous section they were entirely free. Spines have nearly, and dissepiments have quite disappeared, but some of the tertiary septa are still joined to the secondaries. There are still 3 secondaries in the right cardinal, and 2 in the left, (right of fig.) though here a thinner septum has appeard, while each counter quadrant has six secondary septa. The counter septum itself is very thin and thread-like at its inner end, giving the appearance of a counter fossula.

From the sections it is apparent that dissepimental tissue of the convex inward or cystose type, is characteristic of the early stages of the coral, the septa here being much thickened subsequently by stereoplasm. Later these dissepiments break up into spines, and finally these spines disappear. New dissepiments may, however, form in later stages.

So far the sections have not definitely indicated the existence of the horizontal carinæ characteristic of the genus, though some of the spines may be cross-sections of these. In longitudinal sections, and worn specimens of the species from Shansi, these carinæ are seen.

Horizon and Localities: A fairly.complete specimen (Plate I, fig. 5a, b) was found in a dark nearly black calcilutyte, where it is associated with a *Textularioid* and other Foraminifera. This was obtained by Dr. C. F. Erickson at Shih-lin Yuan, Kung Hsien, Honan. The specimen sectioned and described above came from a similar rock from the Poshan or Taiyuan series of Tung Chuang, I-Hsien, Shantung. This is associated with *Lophophyllum acanthiseptum.* Other specimens were obtained by C. C. Wang above the fourth coal seam at I-Hsien Shantung in dark crinoidal limestone. The species is not uncommon in the Kuantikou limestone of the Taiyuan series of late Viséan (or early Moscovian) age in the Taiyuanfu region, where it is associated with *Lophophyllum acanthiseptum* Grabau, from which it can not be distinguished by external characters, unless the calyx, or a section near it, is shown. The species appears to be widespread. Its age is probably in all cases late Viséan or early Moscovian.

Genera **LOPHOPHYLLUM** Edwards and Haime and **LOPHOCARINOPHYLLUM** Grabau (gen. nov.)

The genus *Lophophyllum* is the terminal member of the family *Streptelasmaidæ*, showing in its young stages the simple septal character of *Streptelasma*, with the interseptal spaces sparingly, or not at all furnished with dissepiments. The genus becomes differentiated from the other members of the family by the gradual thickening of the inner end of the counter septum while later this thickened portion is constricted off, so as to appear independently of the counter septum. This forms the characteristic flattened pseudocolumella of the genus. It is not a distinct upward growth from the base of the corallum as is the true columella, which is chiefly restricted to the Hexaseptata, but in the young stage of the corallum, is merely the central portion of one of the four primary septa, the counter septum. The constriction which separates it from this septum in the adult, is analogous to the constrictions which in some Hexaseptata separate the inner ends of all the septa of the earlier cycles, which then, in the adult, form a circle of distinct rods or *pali* opposite to the inner ends of these septa. Because of the similarity of origin, the name *pali-columella* is given to this variety of pseudocolumella. This palicolumella may remain flat, or it may be thickened by secondary stereoplasm, until it becomes a solid rod of circular section.

Lophophyllum is represented in the Carboniferous limestone (Dinantian) of western Europe by a number of species, in the majority of which the pseudocolumella has not yet become fully separated from the counter septum. This represents a more primitive stage in development than is found in typical Carbonic species, where the separation is complete in the adult. As is normal for the advanced genera of this family, the counter quadrants are accelerated, there being sometimes an excess of three pairs of secondary septa in the counter, over the cardinal quadrants. Acceleration of the counter quadrants is also shown by the early appearance of the first pair of secondaries of those quadrants, which appear to develope simultaneously with the four primary septa. (See Duerden 1902, and Gordon 1906).

As will be more fully shown under the description of *L. acanthiseptum*, the Chinese species appear to have a distinct origin, their youthful stages being characterized by the development of carinæ of the *Lopholasma* type, visible in cross-section as septal spines. On this account they may be separated under the generic term *Lophocarinophyllum* Grabau (gen. nov.) with *L. acanthiseptum* Gr. as the genotype. (For further discussion, see pp. 51, *et seq.*).

Lophophyllum proliferum (Mc Chesney.)

1859 *Cyathaxonia prolifera* Mc Chesney, Description of new species of fossils p. 75.
1872 *Lophophyllum proliferum* Meek, Geol. Rep. Nebraska, p. 144, pl. 5, fig. 4.
1873 *Lophophyllum proliferum* Meek, Geology of Illinois, Vol. V. p. 560, pl. 24, fig. 1.
1877 *Lophophyllum proliferum* S. A. Miller American Palæozoic fossils, p. 57.
1883 *Lophophyllum proliferum* Kayser, in Richthofen China, vol. IV. p. 184, pl. XXIX, figs. 7-10.
1902 *Lophophyllum proliferum* Duerden, Johns Hopkins University Circular, Jan. 1902, with serial sections.
1909 *Lophophyllum profundum* Grabau & Shimer, North American Index Fossils, vol. I. p. 76, fig. 119. (Upper figure only.)

This typical North American Carbonic species has been identified by Kayser among the Upper Carbonic fossils of the Loping region. The specimens obtained by him, a dozen more or less imperfect individuals, show a gently curving simple horn-shaped corallum, from 2 to 3 cm. in length, and a calycinal diameter of 5.4 cm. The epitheca is thin, with moderately strong wrinkles; septal grooves well shown, exhibiting the pinnate arrangement. Short radiciform epithecal prolongations are occasionally developed on the lower end. Calyx of circular section, moderately deep; fossula not recognized with certainty. Pseudo-columella exert, laterally compressed. Septa from 28 to about 50, alternating long and shorter, the longer ones (secondaries and primaries) reaching the pseudocolumella, and sometimes slightly twisted at their inner ends. A longitudinal section shows the presence of a few slightly arched tabulæ in the basal portion.

The figures given by Kayser show the essential characters of the American form, the most pronounced feature of which is the laterally compressed and vertically striated palicolumella.

The compressed character of the columella is shown in Kayser's fig. 8, but in the calyx of the most perfect specimen figured by him, it appears to be thickened more than is normal for this species.

No other specimens of this coral have so far been obtained. It should however be noted that some specimens of *L. ancanthiseptum* show in the calicinal portion the essential characters of *L. proliferum* and can only be distinguished with certainty by sectioning.

Horizon and Locality: The specimens described and figured by Kayser came from thin limestone beds intercalated in the coal series, in the Permo-Carbonic of Loping, Hsin-Chau-Fu district, province of Kiangsi. From the close analogy of the

Loping fauna with that of western North America, it is not surprising to find in it the American species of *Lophophyllum*, but apparently this does not occur in any of the other Carbonic faunas of China. The possibility, that the Loping corals belong to one of the species described below, rather than to *L. proliferum*, must not be overlooked, though it is not likely that it is referable to one of the species from the Taiyuan series, because of the difference in age.

Lophophyllum pendulum Grabau (sp. nov.)

Plate I, Figs. 15a, b. (Holotype) Figs. 16a b, 17a b, Text fig. 57 (paratypes).

(cfr. *Lophophyllum proliferum* var. *sauridens* White (?) Kayser in Richthofen China, Vol. IV. p. 195 pl. XXIX, figs. 11-13.)

HOLOTYPE: Corallum with slight curvature only in the lower part, regularly expanding at the rate of 1 in 2 mm. of length, its calicinal diameter at a length of 22 mm. being 11 mm. There are a few irregular but not overprominent growth-wrinkles, but the epitheca is thin, showing the strongly-marked septal grooves with their pinnate arrangement. In the adult the epitheca is, however, strongly thickened by secondary deposits of stereoplasm on the inside, without however obliterating the external features. In the specimen shown in Plate I, fig. 15, the thickness attained by the wall in this manner is slightly over 1 millimeter. Counter quadrants strongly accelerated; the counter septum is pronounced, and still continuous with the much enlarged pseudocolumella. Near the periphery, this septum is about 0.4 mm. in thickness, due to secondary deposit of stereoplasm, but thins away to about half this thickness at the pseudocolumella. It is flanked by a pair of septa which reach about half way to the center, and outside of this by another stronger pair which very nearly reaches the pseudocolumella. These septa are probably the first pair of secondaries, the shorter ones, nearer the counter septum, being the first pair of tertiaries which are longer than the other tertiaries of the corallum. These five septa are separated by very short septa, which would, from their appearance, and similarity to the tertiary septa of the remainder of the corallum, be regarded as belonging to that order. If however the designation above given is correct, as the serial development of corals of this genus, described by Duerden, would lead us to expect, those four short septa of the counter quadrants must be regarded as quaternary.

Beyond the longer septa, here designated the first pair of counter secondaries, are six further septa on each side, somewhat shorter than the first, except the last two, which are much shorter, reaching at the point of section only half-way to the center.

Between them are short tertiaries. Thus there are seven secondary septa in each counter quadrant, together with seven short tertiaries (the last next to the alar), a long tertiary next to the counter and two short quaternaries, or 17 in all.

The alar septa are less prominent than the counter, not reaching the pseudocolumella in the plane of the section, and they are followed by three slightly shorter secondary septa and four very short tertiary septa in each cardinal quadrant, the last of the tertiaries being next to the much shortened cardinal septum, which by its abortion, forms a prominent fossula. Thus the total number of septa in each cardinal quadrant is 7, as compared with 17 in each counter quadrant.

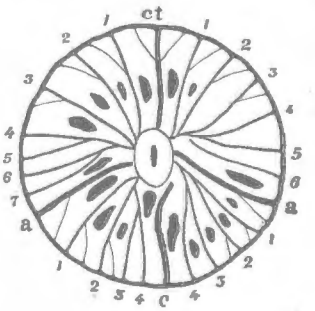

Fig. 57.

Figure 57. *Lophophyllum pendulum* Grabau. Cross-section of one of the paratypes near the middle of the caliculum, showing arrangement of septa (*c*, cardinal, *ct*, counter, *a,a*, alar septa). Enlarged.

A few of the septa are characterized by short hook-like appendages. The pseudocolumella is centran, large and broadly oval in section, due to excessive thickening by stereoplasm. In the holotype its cardino-counter diameter is 3.3 mm. and its lateral diameter 2.5 mm. The center still shows indications of the original flat character comparable to that of *L. proliferum*.

PARATYPES: Another specimen of the same species associated with the preceding, but with fewer septa (a younger specimen, 16 mm. long) was sectioned near the middle where the diameter is 6.5 mm. It shows the septal arrangement represented semidiagrammatically in text fig. 57. The septa are distinctly arranged in four groups though in the upper part of the same specimen they are radial (except for displacement by crushing of the specimen). The counter septum is margined by two short tertiary septa. The palicolumella is already separated from it and surounded by a distinct zone of stereoplasmic material analogous to that which thickens the septa to such an extent, that only minute interseptal loculi (represented in black in the text figure) remain. In spite of the deposit of stereoplasm, the central flat character of the pseudocolumella is pronounced. Surrounding it is a series of minute paliform structures which appear to be the similarly severed inner ends of the secondary septa, though not always aligned with them. Such structures are also indicated in *Lophophyllum proliferum* in a section near the upper end, given by Duerden (1902 Fig. 7) and reproduced by Gordon (1906, Figs. 7 & 14).

Dissepiments very sparingly developed. In the upper portion they generally appear to be absent.

Two silicified specimens from the Upper Dinatian (?) limestone of Honan, show further variations of this species. One of these (Plate I, figs. 16a, b.) is moderately curved, and has the cardinal septum on the side of greatest curvature. The other (Plate

I, figs. 17a, b), less well preserved, is more strongly curved, and has the counter septum nearly but not quite on the side of the greater curvature. The pseudocolumella is exert, broadly oval in section and continuous with the counter septum *i.e.* the thickened part of it is in such a connection, the original inner portion has been dissolved away. Calyx of moderate depth, the septa radially arranged except those of the cardinal quadrants which on the inner side still bend slightly towards the central plane. As the septal grooving on the outside of the corallum is largely obliterated in silicification, it is not possible with certainty to locate the alar septa, but from the appearance of the septa themselves, it seems that there are three secondary septa in the cardinal quadrants, the cardinal septum being very short and situated in a broad, well defined fossula. Very short tertiary septa occur in all the interspaces. The counter septum is flanked by the intermediate septa, regarded as enlarged tertiaries, with minute quaternaries on either side (4 in all.) The succeeding septa are strong and reach the thickened pseudo-columella except where broken. There are six of these on one side and 5 on the other. Minute tertiaries occur in the interspaces. Altogether then, counting septa of secondary and higher orders, there are 15 and 13 in the two counter quadrants while each cardinal quadrant has only 7. Dissepiments are wholly wanting in the upper part of the corallum.

The measurements of the specimen illustrated in Plate I, fig. 16a, b are: length on curved side (estimated) about 27 mm. (the apical portion is broken away); diameter of calyx 10 mm. Cardino-counter diameter of pseudocolumella 2.5 mm., transverse diameter 1.5 mm.

Comparisons. This species, while of the general size and form of *L. proliferum*, differs from it in several important features. The form of the Chinese species is more gently tapering, while the much thickened, broadly oval pseudo-columella, still in connection with the counter septum, readily distinguishes it. This species is as a rule more accelerated in the counter quadrants than *L. proliferum*, but this is not always readily ascertainable. The fossula too, is more pronounced than it is in *L. proliferum.*

Kayser has figured several specimens of a slender *Lophophyllum* with rod-shaped pseudocolumella, which he obtained with *L. proliferum* (?) from Loping. He refers these doubtfully to White's variety *sauridens* of *L. proliferum**, although the latter are much larger. He speaks of the columella as more or less polygonal, but his figures show the section to be circular. Unfortunately its relation to the counter septum can not be determined, and as no new material has come to hand, the relationship must for the present remain in doubt. The difference in the form of the columella would seem to be

* White in Wheeler's Rep. Expl. Exped. west 100th mer. p. 101. pl. 6. fig. 4. 1875.

a distinctive character, however. In any case, our species can not be referred to White's variety.

HORIZON AND LOCALITIES: The holotype, having been sent to America and back, was unfortunately separated from its label, and hence the locality is in doubt. It appears to have been obtained from a shaly deposit (judging from its preservation) and probably came from south China (probably Yunnan). Another specimen, of which a section is given in text fig. 57, was associated with it, as was also the holotype of *Tachylasma cha.* The horizon is probably late Lower Carboniferous (Dinantian) though judging from the acceleration, it might be regarded as younger. The paratypes illustrated in Plate I figs. 16 & 17 came from a black marine calcilutyte with *Productus* etc., obtained by C. F. Erickson at Shih-lin-yuan, Kung Hsien, province of Honan, and are probably of the same age. Another specimen of this species was obtained from black crinoidal limestone, at Tung Chuang, I-Hsien, Shantung. (Poshan or Taiyuan Series). It also shows delicate spines on some of the septa. Two specimens have been obtained by Mr. Norin from the Hsiehtao limestone near Tsin-szü-tsun 42 li S. W. of Tai-yuan-fu, Shansi. This limestone is in the Taiyuan series, which is definitely assigned to the Dinantian (Lower Carboniferous) representing probably the Viséan of Europe. Still another specimen was obtained by Mr. Norin in the Shihchinakou limestone of the Taiyuan series, at Kiau-mên-chien S. E. of Taiyuanfu. A specimen apparently of this species was obtained by Messrs. C. C. Liu and J. C. Chao in a gray limestone with *Productus* sp. in the coal series of the Changhing Coal Mine, Chekiang.

Lophophyllum (Lophocarinophyllum) acanthiseptum Grabau (sp. nov.)

Plate I, figs. 6 a, c; 7 a, c; 8 a, c, e; 9 a, c, e, f; 10 c; 11 c; 18-21.

Text figures 58-65.

(cf. *Lophophyllum frechi* Lorenz, Zeitsch. d. deutsch. geol. Gesellschaft. 1906, p. 91, pl. VI, fig. 7.)

Corallum small, slender, enlarging somewhat irregularly and moderately curved. Epitheca originally thin, but showing strong concentric growth lines which on crossing the strongly marked interseptal ridges give them a regularly nodose or subspinose appearance. Occasional irregularities of growth occur. On the inside, the epitheca is thickened by secondary deposits of stereoplasm. Calyx apparently of moderate depth but rarely shown because of compression of the specimens. Pseudocolumella prominent, laterally

compressed, and rather pronouncedly exert. Where the epitheca is worn away, the septa are seen to have numerous strong irregularly-placed, generally alternating but occasionally nearly opposite, carinæ, which extend outward and have their ends bent upwards.

These carinæ are in all respects like those of the genus *Lopholasma*. In transverse section, at right angles to the axis, one or the other of the upturned edges of the carinæ is frequently seen, appearing as a thin lateral branch septum, parallel to the septum to which it belongs, or as a slender spine from the septum and more or less parallel to it; or the septum appears to be split longitudinally for a greater or less length, thus forming a "double septum". In oblique section the carinæ appear as curving spines upon the sides of the septa.

A section of the pseudocolumella a short distance below the calyx, has the appearance of that in *L. pendulum*, being greatly thickened by stereoplasm. Farther down, it is merged in the general stereoplasmic mass, which unites the inner ends of the septa. It is pendulant from the counter septum.

A specimen (Plate I fig. 20) 23 mm. in length along the curvature, has a diameter of about 9.5 mm. at the upper end, which is some distance below the calyx rim. The specimen shows regular tapering of about 1 in 2.4. Other specimens show more rapid tapering. Dissepiments sparingly developed.

A long slender specimen (Pl. I fig. 21) from the Hsiehtao limestone of the Taiyuanfu region (loc. 39), appears to represent extremes of elongation in this species. The length preserved from the calyx rim to the basal part of the fragment is 41 mm., and the diameter at the base is 7 mm. The calyx is crushed, but 15 mm. below its top the diameter is 9.5 mm. The rate of tapering is thus about 1 in 10, and the total length of the specimen was probably between 50 and 60 mm. The columella is strongly exert and tapering upwards.

A number of sections of this species at oblique angles have been obtained, and these show characters not ordinarily seen in normal cross-sections. They also show the progressive changes in development and will therefore be described at some length.

The largest section seen (Text fig. 58) has maximum and minimum diameters of 15 and 19 mm. respectively, the maximum diameter being due to the obliquity of the section.

This specimen, which came from Ch'i-Ts'un, I-Hsien, Shantung, shows a well-developed, laterally compressed pseudo-columella, of elongate oval section, with a tapering end towards the counter septum with which, at this stage, it still maintains

a faint connection. Its transverse diameter is 1.4 mm. its axial, about 2.5, or with the tapering prolongation 4 mm. The counter septum is slightly stronger than the others, tapering to the point of junction with the pseudo-columella. The septa of the left side (the right as the section is oriented in the figure, the section being reversed), are practically all of the same size so that it is not possible to say if the first long septum is a secondary or a tertiary one. Nor is it possible in this section to determine the alar septa. Altogether there are 10 long septa in the left lateral quadrants (right in figure 58) and 10 in the right, (left in figure 58) differing markedly in character. On the left (right*) they are all simple except two, and separated by shorter septa, which are longer in the counter than in the cardinal quadrants. The last two septa of the left (right) cardinal quadrant are irregularly thickened, and from the salient points project short horn-like spines, an outer, which projects laterally from the septum on the anticardinal side, and an inner (nearer the center of the corallum) on the cardinal side, which projects inward.

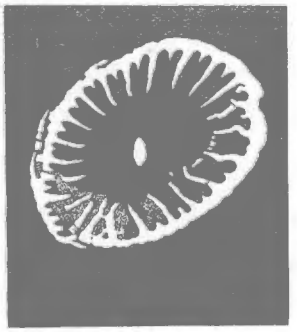

Fig. 59.

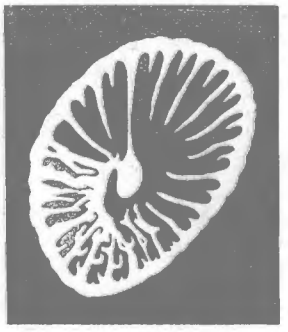

Fig. 58.

Figure 58. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Gr. Oblique section of the largest specimen seen (x 2.5) (reversed) Figure 59. Another specimen sectioned through the calyx, showing freely projecting pseudocolumella.

The cardinal septum is shorter than the secondary septa. It is thickened for half its length from the periphery and then divides into three parts, an inner thin prolongation, deflected towards the right, and two somewhat shorter spine-like spurs. This gives it the appearance of an irregular *trident.*

The secondary septum next to it, on the right, (left in fig. 58) has three short inward projecting spurs, one on the anticardinal side close to the point of origin, a second on the cardinal side, at about one fourth the length of the septum, and the third on the anticardinal side at a little more than half the length of the septum. The next preceding septum is similar, but has an additional blunt spine on the cardinal side. The other septa are similar, but have progressively less developed spines as we proceed counterwards, the spine on the cardinal side being finally the only one, this then being more strongly developed. The last two septa are without spines. All the long septa on the right side (left in fig. 58) except that next to the counter and that next to the cardinal are joined together by stereoplasm, and the close approximation of the last septum of the

* The word in perentheses refers to the position in the figure which, it must be remembered, is reversed.

cardinal quadrant to the preceding also gives it the appearance of being joined to the others.

Another specimen from this locality (Text fig. 59) is sectioned obliquely from side to side the minimum and maximum diameters at the point of sectioning, being 9 and 12 mm. respectively. This section is only a short distance below the calyx rim, and shows only the upper ends of the septa and the pseudocolumella. The latter is isolated, showing its exert character. Its longer diameter is 1.3 mm. its shorter 0.5 mm. There are 19 secondary septa in addition to the four primary which, except the cardinal, are indistinguishable from them in size and disposition, thus making 23 in all of the longer septa. The cardinal septum is however slightly shorter. Short tertiary septa occur between the others. Both the epitheca and the septa are thickened by secondary stereoplasm the former more than the latter. No septal spines are shown in this section which is indistinguishable from one of *L. ropliferum*.

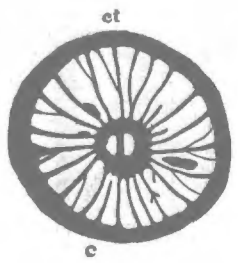

Fig. 60

Figure 60. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau. Section of the specimen shown in fig. 59, about 15 mm. lower; reversed (c. cardinal; ct. counter septa). (Enlarged about 2¼ times).

The corallum is incomplete, its greatest length was originally in the neighborhood of 25 mm. It is further strongly curved, and the sides show well the septal grooves.

A section about 15 mm. below the one described, where the corallum has a diameter of 12.5 to 13 mm. is shown in text figure 60 (reversed). The septa are all united medially by stereoplasm while the pseudocolumella is continuous across the center of this deposit, and apparantly is still a part of the counter septum. In the cardinal quadrants several septa show the short thick curved spine-like processes, characteristic of this species, these extending either laterally or for the most part pointing outwards (towards the periphery). Some of them however point inwards. Dissepiments present but not prominent.

A section of a corallum from Tung Chuang, I-Hsien, Shantung, seen from the basal side, is shown in Pl. I. fig. 6a. The maximum and minimum diameters are 14 and 7.5 mm. respectively, the difference being due to the obliquity of the cut. The section is reversed with reference to the orientation adopted. The epitheca is strongly thickened by stereoplasm. The cardinal septum is short and simple, forming a large fossula (lower left hand side of figure). The two secondary septa on the right next to the cardinal, (left in figure) are long simple and radial, but united at their inner ends by stereoplasm. All the other septa are united into one group by stereoplasm which also includes the pseudocolumella, the outlines of which are visible in the center of the mass. The third (apparently the alar septum) and the fourth septa on the right (left in figure) are also

simple, but the next one has a strong outward pointing spine on its inner anticardinal side. The next two on this side have two spines each, one on either side, while in the next two the spines have developed to such an extent as to make the septum appear double. This appearance is due to the fact that the upturned margin of the carina is sectioned.

The next one is simple, without spines, and then follows the counter septum which has a spine on either side, the bases of the spines being in apposition.

To the left of the counter septum (right in figure) are five septa, each with from 1 to 3 spines. The sixth septum has a spine joining it to the periphery while the seventh is short and joined to the alar (8th) in its outer portion. It becomes free higher up as shown in the next section. The ninth is a double septum and the tenth, next to the cardinal, a simple strong septum. There are thus ten long septa on each side of the cardino-counter axis. One on each side is an alar septum which leaves nine for the two quadrants. So far as the septa themselves permit us to judge, there are seven septa in each counter and only two in each cardinal quadrant, which would indicate an enormous acceleration of the counter quadrants. No dissepiments are shown in this section.

A section of this specimen 3 mm. above that just described (nearer to the calyx rim) and parallel to it, is shown in fig. 7a, Pl. I. This section is normally oriented, the corallum being viewed from above, and hence the parts are reversed with reference to the preceding section. Both sections are at angles of about 45 degrees to the axis of the corallum, the counter quadrants being cut much lower than the cardinal. In this section the counter quadrant is still attached to the columella which is of oval section about 2 mm. wide, and about 2.5 mm. long (it must be remembered that the length is exaggerated owing to the obliquity of the cut). In the section the length is 3.3 mm. The spines of the counter septum have been displaced laterally being no longer directly opposed as in the previous section. To the left of the counter septum (which corresponds to the right in the previous section) there are six simple septa with inward pointing spines, followed by a short septum without spines, and then by a long septum which is the alar septum. These two were apparently united in the lower section but have now become completely and widely separated. Beyond the alar, there are two shorter septa before the cardinal is reached. This makes 10 septa in all, and shows that the double septum has again united into a single one (*i.e.* the double appearance was due to sectioning of the carina edge).

A partial section, perhaps 2 mm. higher (Pl. I, fig. 8a reversed), shows only the counter quadrants. The septa of this quadrant on the right (left of the counter septum as seen in the preceding section), which were strongly spinous, have lost their spines towards the upper edge of the calyx and become simple (here shown on the right side). The

counter septum is stronger than the others, but the columella does not reach so high, being unrepresented in this section.

A younger individual of this species is also shown in this rock fragment. Six successive sections of this are shown in figs. 6c, 7c, 8c, 9c, 10c, & 11c, Pl. I, these sections being nearly at right angles to the axis. Four of these (7c-10c) are shown enlarged in text figures 61-64. In the youngest (reversed) which is 2.5 mm. in diameter, the interseptal spaces have been almost obliterated by the deposition of stereoplasm on the septa. Strong interseptal ridges and septal grooves are, however, shown on the outside.

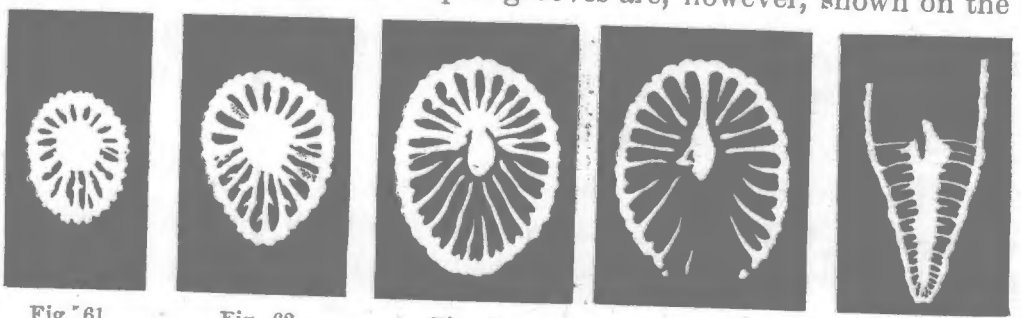

Fig. 61. Fig. 62. Fig. 63. Fig. 64. Fig. 65.

Figures 61-65. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau. Sections shown in Plate I, figs. 7c, 8c, 9c, 10c and 9f enlarged about 2½ times. Figs. 61-64. A series of slightly oblique, transverse sections showing development of septa and pseudocolumella. 61 and 63 are normally oriented, 62 and 64 are reversed in position. Fig. 65. Median longitudinal section showing the thickened pseudocolumella, and the Lopholasma-like character of the carinæ, which appear here as horizontal lines. (Enlarged x3).

The second section is 3 mm. higher, on the opposite side of the same slice (Pl. I, fig. 7c normal, text fig. 61). It has maximum and minimum diameters of 6 and 4.5 mm. respectively, and shows the cardinal septum well developed with a spine on either side. On the left side there are three septa in the cardinal quadrant joining one another and the alar septum, which is long. There are four septa also joined into a group, in the counter quadrant. On the opposite side these four are well developed and a fifth, much thinner, has begun to appear next to the alar. The third (innermost) septum of the cardinal quadrant on this side is much smaller and shorter than that on the opposite side. Several of the septa in the cardinal quadrants have short spines, but those of the counter quadrants seem to be without them, or with only very incipient ones. All the septa are united in the center into a stereocolumella.

A third section is taken about 2 mm. higher on another slice (Pl. I, fig. 8c, text fig. 62) where the diameters are 7.5 and 6 mm. respectively. The position here is reversed so that the parts on the right side correspond to those on the left in the preceding section. The septa of the cardinal quadrants are still spiny, indeed more strongly so than in the preceding section, while those of the counter quadrants show no spines. The alar septum on the left (right in section) is double, and the three septa of

each cardinal quadrant have now become distinct. There are now five distinct septa in the counter quadrant on the right (left in section) while a thin fifth one appears on the left (right in section). All the septa are still united into a stereo-columella, the palicolumella not yet appearing in distinct outline. There are as yet no tertiary septa. The septal grooves and interseptal bulgings are still very strong. Epitheca moderately thickened by stereoplasm.

The fourth section (Pl. I, fig. 9c, text fig. 63) is 3 mm. higher on the opposite side of the same slice with section 3. Here the orientation is again normal. The diameters are 10 and 7 mm. respectively. The septa of the cardinal quadrants are now free and radial. There are 2 on the right and 3 on the left, the third one on the left (next to cardinal), being shorter than the others. The cardinal septum has also become shortened to half its previous length (proportionately). All have lost their spines. The alar septa are the longest of the free septa. The counter septa are still united by stereoplasm, except the last on each side which is free, and several of them are slightly spinous. There are six on the left and seven on the right. The palicolumella is now distinct in outline, but still united to the counter septum and to the crescentiform stereoplasm, by its counter side. It is of narrow pear-shaped outline, with maximum width of 1.2 mm. Tertiary septa have now appeared in the cardinal quadrants and the septal grooves and interseptal ridges are no longer so strong. Epitheca moderately thickened by stereoplasm.

The fifth section (Pl. I, fig. 10c, text fig. 64) about 2 mm. higher on another slice, again shows the position reversed. The diameters are 11 (?) and 8 mm. The septa of the counter quadrants are now free, those next to the counter being shorter than the others. The counter septum is still united with the palicolumella. The spinous character of the septa has now disappeared. The sixth and final section (Pl. I, fig. 11c) is close to the calyx margin. All the septa are shortened and the columella is free. It is strongly compressed laterally, and this and its exert character gives the calyx the appearance of that of *Lophophyllum proliferum* from which it could only be distinguished by the other sections.

Two longitudinal sections (Plate I, figs. 8e, 9e, 9f and text fig. 65) of small individuals are associated with the transverse sections, and these are referred to the present species despite their remarkable character and their association in the same slab, with sections of *Lopholasma carbonaria*, as well as *Lophophyllum acanthiseptum*. Their significance consists in the fact that they resemble to a remarkable degree the sections of *Lopholasma carinatum* Simpson a Devonian species. These are shown in text figures 52 and 53 p. 43 reproduced from Simpson (1900 p. 207 Fig. 21-22). That these sections

are referable to *Lophophyllum acanthiseptum* and not to *Lopholasma carbonaria* is shown by the different character in the young of the latter species in which carinæ are apparently absent while the septa are so thickened as to fill the entire space (see p. 44). That these sections belong to *L. acanthiseptum* is also shown by the projecting pseudo-columella.

In the median section (Plate I, fig. 9f, text fig. 65) the calyx is deep and the pseudo-columella projects into it, extending upwards from the bottom of the calyx. Distinct, nearly horizontal carinæ are shown, proceeding from the columella, and reaching the cup wall, when the section is parallel to the septa. In the excentric section (Pl. I, figs. 8e, 9e) the width of these carinæ and their irregular disposition on the sides of the septa are shown. Their outer margins are seen turning upwards. It is these carinæ which in section appear as spines, especially when the sections are oblique, as they are in figures 6-11 in Plate I. In parallel section the edges of the carinæ appear as branch septa.

The almost absolute correspondence of these sections of young *L. acanthiseptum* (except for the projecting pseudocolumella) to those of adult *Lopholasma carinatum*, indicates beyond doubt that the Devonian form holds ancestal relation to our species. As no such structures have been recorded in American species of *Lophophyllum*, while they seem typical of all the Chinese species,* the question of a separate origin of these forms is at once suggested. Our species quite evidently is derived from a *Lopholasma* type of ancestor, possibly directly from the Devonian *L. carinatum*. The development of the American species on the other hand suggests that it is derived from an ancestor of the *Stereolasma* type, possibly from *Stereolasma rectum* in a direct line. If that is the case, our species can not be referred to *Lophophyllum*, but represents rather a parallel development of the *Lophophyllum* structure (i.e. the palicolumella). This might be indicated by the generic name *Lophocarinophyllum nom. nov.* applicable to the Chinese Lophophylloid types.

The total absence of dissepiments and tabulæ in this species is remarkable and would lead some to place it with *Cyathaxonia*. However the septal development and the origin of the columella are quite distinct from those in *Cyathaxonia* (see *postea*) as is also the development of carinæ.

Horizon and Localities: This species was obtained in a brownish limestone (calcilutyte) associated with small crinoidal fragments at Chi-Ts'un, I-Hsien, Shantung above the third coal seam, and in a dark blackish crinoidal limestone, associated with

* The species referred by Kayser to *L. proliferum* (*ante* p. 47) also, apparently, possesses these carinæ as indicated by Kayser's section (*loc. cit.* pl. XXIX fig. 10) though these have been referred to as tabulæ. They however suggest the carinæ very strongly.

Lopholasma carbonaria at Tung-Chuang I-Hsien, Shantung. The age is Carbonic, possibly late Dinantian (Taiyuan series). The species is common in the Kuantikou limestone of the Taiyuan series in the Taiyuanfu region (locs. 27, 38) and also in the Hsiehtao limestone of the same series (loc. 39) where it was collected by Erik Norin. These beds are at present referred to the late Viséan.

Lorenz figures a section of a coral from Poshan under the name *Lophophyllum frechi* sp. nov. Unfortunately it is impossible to determine the generic standing of Lorenz's form from the section. It might belong to the species here described, or it may be a section of the form described above as *Lopholasma carbonaria*. The stage represented by Lorenz's section is practically alike in the two genera. This makes it necessary to discard Lorenz's name.

Genus **ARACHNOLASMA** Grabau (gen. nov.)

Corallum simple, of moderate size, subcylindrical in the mature, regularly tapering in the young portions. Septa numerous, radiating; dissepiments abundant; center of corallum occupied by a pali-columella, which is joined to the counter septum in the early stages but is free from it throughout the greater part of the corallum. In form the pseudocolumella is laterally compressed and elongated in the direction of the cardino-counter axis, having thus essentially the character of the pseudocolumella in *Lophophyllum*. The pseudocolumella is amplified and strengthened by supplementary tissue in the form of irregular elevated, converging plates, which in section give the appearance of a coarsely cystose structure, which has a rather marked resemblance to a spider's web. Cardinal septum only moderately aborted, there being a scarcely defined cardinal fossula.

The large number of radial septa, the very abundant dissepiments, and the peculiar character of the axial part around the columella, as well as the early separation of this from the counter septum, distinguish this genus from *Lophophyllum*.

GENOTYPE:—*Lpohophyllum sinense* Yabe and Hayasaka.

Arachnolasma sinense (Yabe and Hayasaka)

Text figure 66.

1920 *Lophophyllum sinense* Yabe and Hayasaka, Palæontology of Southern China, plate VI figs. 2a-2g.

This species was figured by Yabe and Hayasaka, but, so far as I am aware, has not been described. However, the figures are well executed and show all the details, including five cross-sections and a partial longitudinal section.

The species is much larger than any known *Lophophyllum* and has more the aspect of a slender *Cyathophyllum*. The maturer portion is nearly cylindrical but the young portion shows gradual tapering with slight curvature. The epitheca is of moderate thickness, allowing the septal grooves and interseptal ridges to be seen on the exterior.

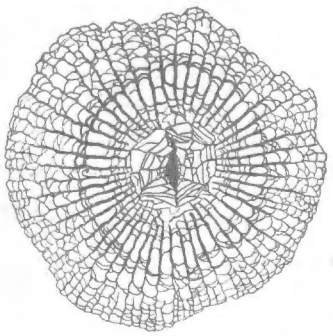

Fig. 66.

Figure 66. *Arachnolasma sinense* (Yabe and Hayasaka). Copy of one of the cross-sections (enlarged x1 ½) figured by Yabe and Hayasaka.

In the youngest section shown, where the diameter is only about one-third that of the adult, the columella is continuous with the counter septum, but in all the others it is free. Even in the youngest state shown, the spider-web arrangement of the cysts around the columella is seen and this persists throughout.

In the largest section shown (diameter 28 mm. text fig. 66) there are 49 well-developed septa (1st and 2nd orders) with less well-marked tertiary septa. Towards the periphery, the septa become somewhat illy defined merging into a more or less pronounced cystose zone. They stop short of the center, where the arachniform cysts occupy about 2/7 of the diameter. The septa are thickened in their middle third but become thin both towards the center and the periphery. Sometimes a strongly marked series of dissepiments occur at the point where the thickening commences, giving the appearance of an inner wall.

The pseudocolumella is long and narrow in the maturer parts but more oval in the younger stages.

Horizon and Locality: The specimen figured by Yabe and Hayasaka came from the Lower Carboniferous beds East of Ai-Chia-Ping, Wei-Ning-Hsien, Province of Kweichou. No further material has been obtained.

Genus **Amplexus** Sowerby

This genus was founded upon the Dinantian species *A. coralloides* Sowerby, which is characteristic of the Carboniferous Limestone of Ireland, England, Belgium, the Urals and more doubtfully of the United States. Its essential character are: the

cylindrical form, above the rapidly tapering initial portion; the thin equally developed septa, which are widely spaced and do not extend beyond the marginal portion of the corallum; and the well-developed and numerous tabulæ which extend entirely across the corallum in a more or less regular manner and are close together. The septa extend as narrow ridges upon the outer margins of the tabulæ.

In typical British specimens of *A. coralloides*, the fossula is only slightly or not at all developed. Edwards and Haime state (1852): "A small depression, corresponding to the septal fossula, is visible near the wall, and is always more distinct on the last tabula than on the others" (p. 174). The fossula is an incipient siphonofossula, as might be expected from the abundant development of tabulæ. In the large specimen figured by Edwards and Haime, this is not shown, nor is there any apparent shortening of the cardinal septum. The small cylindrical form, which should probably be regarded as a distinct mutation, shows however the faint bulging on the under face of the tabula, together with a slight shortening of the septum at this point (presumably the cardinal septum). De Koninck (1872 pl. V. figs. 1a 1b) figures a large specimen, probably from Belgian rocks (Dinantian), which shows a well-developed siphonofossula with an aborted (cardinal?) septum. Thus it appears that in the typical species of the genus the siphonofossula is developed only in the adult stages of accelerated individuals, but is absent in others and in the young. (It is evident that the small cylindrical form figured by Edwards and Haime *loc. cit.*, is not the young of the larger form, but the adult of a slender variety). The young conical forms figured by Edwards and Haime, and by de Koninck, are without a fossula, and in form are streptelasmoid. They further agree with primitive *Streptelasmaidæ* in the absence of dissepiments or other endothecal tissue, except the tabulæ, while the absence of the fossula in the young shows that the form can not be derived from the zaphrentoids in which this is developed at an early stage. Unfortunately no developmental studies of the young of *A. coralloides* have been made and we therefore do not know if the counter quadrants are accelerated as is the case in the *Streptelasmaidæ*. The apparent close agreement, however, of the young of *A. coralloides* with the adult of *Amplexus hamiltoniæ* from the Hamilton (Middle Devonian) of New York State (U. S. A.)* is evident. This form is a typical streptelasmoid in the young, showing the quadripartite arrangement of the septa which reach to the center. This is sometimes retained in specimens up to the diameter of 6 mm. or more. In others the change towards an amplexoid structure appears earlier. The young is without tabulæ, but these develope in the neanic stage, when the septa begin to shorten. Tabulæ are

* See Grabau and Shimer 1909. N. A. Index fossils I, p. 59. fig. 86.

never so numerous or crowded as in the adult *A. coralloides*, and this is to be expected in an earlier, probably ancestral, form. This is probably also the character of the young of *A. coralloides*.

It must be clearly understood, that the amplexoid character, *i.e.* the well-developed tabulæ and shortened septa, is a purely homœomorphic character, indicating a stage in development, and not necessarily genetic relationship. In fact these characters are known to reappear in a number of distinct genetic series.

Lindström has described several species from the Silurian of south China, which he refers to *Amplexus*. Of these his first species *A. viduus* can not be left under this genus. It is a compound corallum, composed of a number of distantly placed narrow cylindrical corallites, 4 mm. in diameter. Septa are not visible but tabulæ are very numerous. This form is here referred to the genus *Synamplexus* nom. nov.

The two other species described by Lindström are more fully discussed below. They too are probably not referable to the same genus with *A. coralloides*, but until further material is obtained, which will permit the study of young stages, their precise generic reference must remain in doubt.

In the Middle Devonian of North America we find several other species with amplexoid characters. The most characteristic is generally identified as *Amplexus yandelli*. This is however not the species first described under that name by Milne Edwards and Haime (1851, p. 344, pl. 3. fig. 2). That form is a zaphrentoid with a well-developed siphonofossula, and belongs to the genus *Siphonophrentis* O'Connell (1914) (*Siphonophrentis yandelli* (E & H)). Here probably also belongs *Amplexus cornubovis*, though this species may belong to the genus *Siphonophyllia* Scouler, where it was placed by O'Connell on the supposition that it has a marginal vesicular zone. The figure of *Amplexus yandelli* given by Lambe (1901, pl. 9, fig. 4, 4a 4b) and reproduced by Grabau and Shimer (1909, p. 58 fig. 85) appears to be that of a true *Amplexus* however. To this species the name *Amplexus yandelli* must be restricted and the authorship credited to Billings, though the first illustration was given by Lambe. In this association probably belongs *Amplexus exilis* Billings, from the Onondaga limestone (Middle Devonian) of Ontario. That species is characterized by extremely short septa, their number however being large (64 or more). *Amplexus cingulatus* Billings, from the Upper Silurian beds of the Bay of Chaleurs and l'anse ou Gascon, is probably not a true *Amplexus*.

The species described below as a variety of *Amplexus spinosus* de Koninck, is probably to be regarded as a valid member of the genus.

Amplexus (?) distans Lindström

1883 *Amplexus distans* Lindström, in Richthofen China Vol. IV. p. 63. Pl. VI, figs. 1 & 5.

This is a simple corallum, of moderately straight form, conical, and gradually increasing in width upwards. Septa very short measuring only 4 mm. in length where the radius of the caliculum is 12.5 mm. (diameter about 25 mm.). In transverse section the septa are broad, rapidly tapering to a point, which is bent somewhat sideways. Between the septa, there is developed a gray stereoplasm, forming a narrow peripheral septal, or stereoplasmic ring. In longitudinal section the septa appear as narrow, longitudinal ridges, furnished with distant bent, and sharply pointed spinous prolongations Curved, and strong dissepiments occur on the spiniform processes of some of the septa. Tabulæ thin, and distant, five in the space of 22 mm.

The amplexoid characters of this species consist of the shortened septa and the tabulæ, features which are correlative, and are repeated in a number of genetic series. The present species is in some respects more highly specialized than the Devonian species, and it may be seriously questioned if it can be considered congeneric with the typical species of the genus. This problem can only be settled by a study of the young stages. Then it will probably be found, that this species is an independent development from Ordovician streptelasmoids.

Horizon and Locality: This species is known only from fragments obtained from bed *i* of the Silurian series of Tsau-tien in north-east Szechuan.

Amplexus (?) appendiculatus Lindström

1883 *Amplexus appendiculatus* Lindström, in Richthofen China, vol. IV, p. 63. Pl. VI, figs. 7-8.

Corallum broadly conical, with deep calyx, the walls of which descend vertically on the inside. Rootlike proliferations arise from the margin of the calyx as in *Omphyma* and other Palæozoic corals. In section these proliferations appear nearly solid, having been filled by stereoplasmic deposit on the interior. Only a slender median axial tube remained which later was filled by lighter-colored lime carbonate.

The longer septa (primaries and secondaries) are narrow and straight, reaching nearly to the center of the calyx. The tertiary septa between are very short and sharply pointed. In longitudinal section the septa appear marked by obscure cross stripings. Tabulæ closely crowded and nearly horizontal. Width of calyx 31 mm.

This species differs from others, (except *A. spinosus*) according to Lindström, in the possession of rootlike proliferations, though these are not shown in Lindström's figure. Here as in the preceding species we may question the propriety of placing this form in the genus *Amplexus*, though from fragments alone no other reference seems possible. That it is an amplexoid type, is evident, and that it was probably derived from an earlier streptelasmoid is suggested by the simplicity of its internal structure. It is certainly distinct from those Devonian species the young stages of which have been investigated (i.e. *A. hamiltoniæ*) being much more specialized and quite evidently derived from a different ancestor.

Lindström figured two sections of an elongated form which be considered a variety of this species (Richthofen IV. Pl. VI. figs. 11-12) The sections represent opposite sides of a slice 5 mm. in thickness. The septal arrangement here is that of a very primitive streptelasmoid. In the smaller section, the septa still show some indication of grouping, and for the most part reach the center; two indeed from opposite sides (the cardinal and counter?) are joined in the center. In the larger section, five millimeters higher, the septa are mostly radial, and do not quite reach the center. Dissepiments very sparingly developed; no fossula.

These characters indicate the persistence of very primitive *Streptelasma* characters, to which is added the strong development of tabulæ, the coral in this respect being highly specialized. It is possible that a study of the young will show that this species belongs to the DEUTEROSEPTATA, taking its rank with *Omphima* and *Ptychophyllum*, especially such forms as *Ptychohpyllum richthofeni* and *Pt. cyathiformis* of these same rocks.

HORIZON AND LOCALITY: Occurs with the preceding.

Amplexus spinosus de Kon.

var. **sinensis** Grabau (var. nov.)

Plate I, figs. 22a b, 23.

COMPARE:

1842 *Amplexus spinosus* de Koninck, Anim. Foss, des Terr. Carb. du Belg. p. 28, Pl. C, fig 1.

1852 *Amplexus spinosus* E. & H., British Fossil Corals. p. 176.

1872 *Amplexus spinosus* de Koninck. Nouvelle Recherches sur les Anim. Foss. de Terr. Carb. du Belg. p. 75 pl. VI, figs. 6a, b.

1911 *Zaphrentis spinulosa* Frech; Richthofen China, vol V. p. 62, pl. 10 figs. 7a-b.

In the typical form of this species the corallum is elongate, becoming cylindro-turbinate in the mature part, with somewhat twisted form. In the specimen figured by de Koninck in the earlier publication, the entire corallum is armed with scattered spinose epithecal processes, but in the specimen figured in the later work, only the lower half of the corallum, *i.e.* the expanding part, is thus characterized.

In the variety *sinensis* the corallum is slightly curved, and expands more rapidly than in the typical form. In the earlier portion, where the diameter is only about 6 mm., the septa still meet in the center. There are about 22 of them, slightly irregular, and not thickened by secondary deposits. There are a few dissepiments present at this stage. The septal grooves are moderately developed, and the interseptal ridges are rounded. From them arise the scattered spinose epithecal prolongations. These were hollow radiciform expansions, which may have served the purpose of anchorage as in other corals of this type.

The calyx is very deep, and the septal edges are sharp and denticulated. The central flat tabulated area, over which the septa do not extend, occupies a little more than one fourth the diameter of the corallum at that point.

This variety is distinguished chiefly by the smaller size and more rapid expansion of the caliculum, the more numerous septa, which in the typical form are about 16, and the somewhat smaller central non-septate area. The epithecal spines are of the same character as those of the Belgian form.

Length of a specimen about 17 mm. calicinal diameter 11 mm.

Horizon and Locality: This variety is represented by two small fragmentary specimens from the Lower Carboniferous (Upper Dinantian) Chihsiashan limestone of Chihsia-shan, (Single-tree Hill) Nanking region, province of Kiangsi. They were associated with other corals found in the European Viséan. The species was originally obtained from the Carboniferous limestone of Tournay Belgium, and the Isle of Man.

Frech figured a specimen, without description, from the same horizon and locality, referring it to the American *Zaphrentis spinulosa* Edw. & Haime from the Kaskaskia beds of the Mississippi valley. His specimen is much larger than ours (provided his figures are natural size, no statement to the contrary being made). It is however a more retarded form, being still in the *Streptelasma* stage, with the septa reaching to the center, as in the young of our specimens. The coral can not be referred to *Zaphrentis*, and there is no reason for considering it other than a retarded individual of the above described variety of the European species of *Amplexus*.

Genus **METRIOPHYLLUM** Milne-Edwards & Haime.

(Edwards & Haime, Fossil Corals, p. lxxix, 1850, & Hist. Nat. des Coralliaires, T. III, p. 328, 1860).

This genus was erected by Edwards and Haime for the reception of two European Devonian species *M. bauchardi* E. & H. (*Cyathophyllum mitratum* Michelin) from the Upper Devonian of Ferques, in France, and *M. battersbyi* E. & H. from the Devonian of Torquay in Devonshire, England. A third species was described by Mansuy from south China, and is noted below.

The corallum in this genus is simple, conical or top-shaped, and basally attached. The epitheca is complete. Septa fully developed, not interrupted, slightly warped, and arranged in four groups or bundles. Primary septa presenting a four-armed cross. Dissepiments well developed, simple and more or less horizontal, their arrangement being such that they correspond to one another in position, forming incipient tabulæ.

Edwards and Haime suggested that the quadripartite arrangement of the septa indicated relationship to *Stauria*, where the four primary septa are strongly developed, forming a cross, and that this genus formed a transition type to *Cyathophyllum*. This is an error, due no doubt to the fact that at the time when this was written, the normal quadripartite character of the young of the TETRASEPTATA was unknown. In the light of our present knowledge, we must regard the genus *Metriophyllum* as a persistent primitive form, so far as the septal arrangement is concerned. In other words, the septal grouping has scarcely passed beyond the primitive qudripartite arrangement characteristic of the young of corals of this division, while in other respects the coral has developed, notably in the increase in the number of septa, and the abundant development of dissepiments and their tendency to unite into tabulæ.

The counter quadrants in this genus are accelerated, indicating its relationship to the *Streptelasmaidæ* from the more primitive members of which this group is derived. The peristence of the pinnate or quadripartite arrangement of the septa is similar to what is seen in the genus *Pinnatophyllum* Grabau* of which *Cyathophyllum scyphus* is the genotype.

That genus forms the most primitive member of the *Cyathophyllidæ*, being more specialized than *Metriophyllum*, which I would retain among the *Streptelasmaidæ*. It is not impossible that *Pinnatophyllum* is a derivative of *Metriophyllum*, though I am inclined to think, that these genera represent independent lines of development, one, *Pinnatophyllum* in American, the other *Metriophyllum* in Eurasiatic Devonian waters.

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* Devonic Corals of Michigan.

Metriophyllum (?) poshiense Mansuy.

1912 *Metriopoyllum poshiense* Mansuy Paléontogie du Yun-nan Oriental; p. 47, Pl. VII, figs. 8a-d.

The corallum is cylindrical and much elongated. Diameter 7 to 8 mm. Epitheca thin, transverse wrinkles not very prominent. There are thirty-six septa, their length very unequal, somewhat sinuous at their inner extremities, and arranged in four groups. The four principal septa extend to the center, but they are not always regularly opposed, two and two. In some individuals one of the primary septa is not more strongly developed than those of the second cycle. The latter are equal in length, while those of the third cycle are somewhat shorter and those of the fourth not over a millimeter in length. (Mansuy).

It is difficult to form a clear conception of the nature of this coral from the illustration given by Mansuy. The cardinal septum appears to be strongly developed, and so are the alar and the counter septa. But there also appear to be other, equally strongly developed septa, in some cases one, in others two additional. This and the general arrangement of the other septa, suggests rather the genus *Pentaphyllum* de Koninck. Again some of the sections suggest *Tachylasma* Grabau. It is evident that a reëxamination of the types is necessary before they can be properly placed. In any case this coral differs so markedly from the European species of *Metriophyllum*, that its reference to that genus seems extremely hazardous.

Horizon and Localities: The specimens described by Mansuy came from the Middle Devonian (Eifelian) between Po-shi and Si-Eul in Yunnan. Deprat also cites it from similar beds at Hoa-Keuou. No other material has been obtained.

Family 3. **CYATHAXONIDÆ** Edwards & Haime (emend. Grabau).

This family at present includes only the genus *Cyathaxonia* Mich. This is a small slender curved conical corallum with rather strong epitheca that does not show the septal grooves, but shows faint growth-wrinkles. The calyx is moderately deep, its sides marked by septal ridges, while its bottom is formed by the septa which meet in the center, joining a cylindrical pseudocolumella which projects in styliform manner. Interseptal loculi empty, without dissepiments or tabulæ. In the type species *C. cornu* (Michelin), the number of septa is about 36.

The septal development of this species has been studied by Faurot, (1909*) and proves this form to be distinct from that of other known types in the manner of developmental detail. As in the *Streptelasmaidæ*, the counter quadrants are accelerated over the cardinal, but only to the extent of one septum of each order, there being 4 secondary and 5 tertiary septa in the counter, and 3 secondaries and 4 tertiaries in the cardinal quadrants. The tertiary septa are long, reaching the columella. The early stages

Fig. 67.

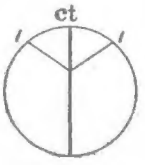


Fig. 68.

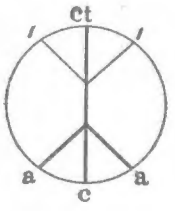


Fig. 69.

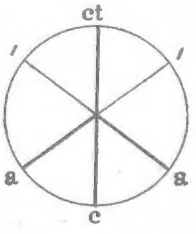


Fig. 70.

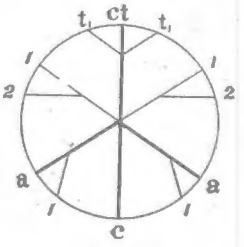


Fig. 71.

Figures 67-71. *Cyathaxonia cornu* (Michelin) a series of cross-sections showing the order of development of the septa (the pseudo-columella is omitted, see text fig. 31). Enlarged. (Modified after Faurot.) c - cardinal, ct - counter, a,a - alar septa; 1; 2; 2; etc. secondary septa in the counter and cardinal quadrants; t, tertiary septa.

however show that the acceleration of the counter quadrants is in reality much more pronounced than is the case in the Streptelasmaidæ, for the first pair of secondary septa appears in the counter quadrants before the alar septa appear. The earliest stage recorded by Faurot, shows a continuous cardino-counter septum crossing the corallum. Then appears the first pair of secondaries next to the counter, after which the alar septa appear near the cardinal.

As these septa develope, their points of junction move along the median cardino-counter septum, until they meet in the center, thus forming six equal septa meeting in the center. After that the septal development is fairly uniform and similar in all the quadrants, except that, as in other accelerated types, the first pair of tertiaries appears next to the counter, along with the second secondary in each quadrant, and the counter quadrants are always one pair of septa ahead of the cardinal. Thus the first pair of secondaries of the cardinal quadrants appears almost simultaneously with the second pair of secondaries, and the first pair of tertiaries, in the counter quadrants. The first pair of secondaries acts as the supporting or guiding septum in the counter quadrants, the succeeding secondaries at first joining it. The same office is performed by the alar septa for the secondaries of the cardinal quadrants. But the most striking feature in the order of development is the close sequence in which the tertiary septa follow the secondaries. Thus in the counter quadrants the first pair of tertiaries developes after the first pair of

* Annales de Paléontologie (Marcellin Boule) T. IV, pp. 69-108.

secondaries, and on their counter side. The second pair of tertiaries developes after the second pair of secondaries and again on their counter side. The same succession holds for the third and 4th secondaries, and their corresponding tertiaries. Finally the fifth secondary appears next to the alar and is at first joined to the fourth after the manner of the preceding septa. This septum however never attains the strength of the other secondary septa, while the corresponding fifth tertiary does not appear.

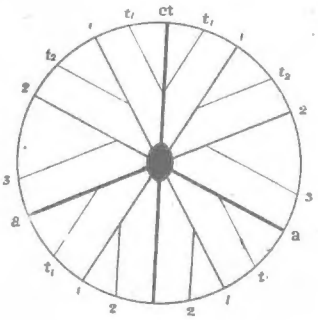


Fig. 72.

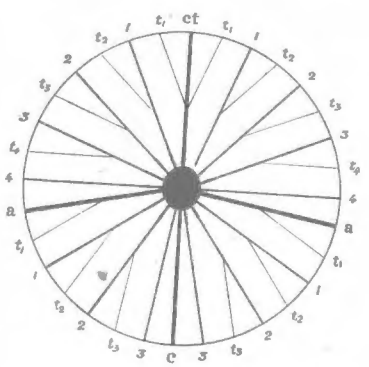


Fig. 73.

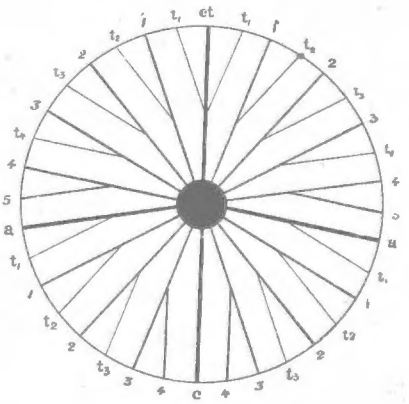


Fig. 74.

Figures 72-74. *Cyathaxonia cornu* (Michelin)—Three consecutive sections of the later stages, showing the order of development of secondary and tertiary septa. Enlarged (Modified after Faurot.) 1-4, and 1-5 secondary septa in the cardinal and counter quadrants respectively; t_1 - t_3 tertiary septa.

In the cardinal quadrants the order of septal development is precisely similar, the first tertiaries appearing after the appearance of the corresponding tertiaries in the counter quadrants, but before the appearance of the second pair of tertiaries in those quadrants. Each pair of tertiaries of the cardinal quadrants appears next after the appearance of the corresponding secondaries, and before the appearance of the next secondary. The tertiaries always appear behind i.e. on the alar side of the corresponding secondaries. The columella is outlined early by a thickening of the central meeting point of the septa. It does not belong to a single septum as in *Lophophyllum.* Some of the stages of development of this coral are shown in text figures 67-74, copied from Faurot's article but with the numbering of the septa changed to bring out more truly their relationship.

CYATHAXONIA occurs in the Carboniferous limestone (Dinantian) of Belgium, England, Ireland and elsewhere in Europe. It has not yet been found in China, but it is not at all unlikely that it will be obtained.

EXPLANATION OF

PLATE I.

PLATE I.

Corals from the Devonian and Carboniferous (*Drawn by K. C. Liu* 劉 光 城)

Fig. 1. *Stereolasma rectum* Hall.....p. 32

a. Side view of a corallum with upper part cut away; slender species of *Hederella* attached on one side. Natural size.

b. Section of the same a short distance below the calyx. Twice natural size. Middle Devonian, Tungshan, Kütsing district, Yunnan. V. K. Ting coll. (G. S. Ch. cat. 141).

Fig. 2. *Tachylasma cha* Grabau.....p. 35

a. Side view of the holotype natural size.

b. Section below calyx, enlarged twice. Carboniferous (?) of Yunnan V. K. Ting coll. (G. S. Ch. cat. 142)

Fig. 3. *Tachylasma aster* Grabau.....p. 38

a. Polished cross-section near the upper end showing adult characters; enlarged twice.

b. Section of the same 3.5 mm. lower, showing an earlier stage. This section is reversed with reference to the preceding one. Enlarged twice; Holotype. Black Permian (?) limestone, Changhsing Coal Mine, Chekiang province (Coll. C. C. Liu and J. C. Chao; G. S. Ch. cat. no. 143)

Fig. 4. *Tachylasma aster* Grabau.....p. 38

Section of another specimen at an earlier stage, showing characters suggestive of *Tachylasma cha*. In the same rock fragment with the preceding (Fig 3). (G. S. Ch. cat. 144)

Fig. 5. *Lopholasma carbonaria* Grabau.....p. 43

a. A specimen with the upper part cut away, showing the strongly curved basal portion; natural size.

b. Cross-section of the same, enlarged twice.

Dark foraminiferal limestone (Lower? Carboniferous); Shih-Lin-Yuan, Kung Hsien, province of Honan. (Coll. C. F. Erickson; G. S. Ch. cat. 145)

Fig. 6a. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau .....p. 51

Oblique section (reversed) on under side of rock slice. Natural size. The cardino-counter axis lies at an angle of about 30° with the horizontal.

6b *Lopholasma carbonaria* Grabau.....p. 43

Section of a small specimen near the base. (reversed)

6c. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51

Section of a specimen near the base or initial point (reversed). All natural size

Carboniferous limestone, Tung Chuang, I-Hsien, Shantung province. (G. S. Ch. cat. no. 146)

Fig. 7a. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau..... .....p. 51
Section of specimen 6a, about 3 mm. higher. Upper side of the same rock slice. This shows normal orientation with counter septum (top) on upper left hand side. Natural size.

7b. *Lopholasma carbonaria* Grabau.....p. 43
Section of the individual shown in 6b., 3 mm. higher; upper side of same slab.

7c. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
Section of the specimen 6c. about 3 mm. higher up (normal). Orientation reverse of that of the specimen Fig. 7a. the cardinal septum on the left. (See text fig. 61)

7d. *Lopholasma carbonaria* Grabau..... .....p. 43
Section of a very early stage.

7e. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
Part of longitudinal section. (See 8e, 9e.) All natural size, same horizon and locality as Fig. 6. (G. S. Ch. cat. 146)

Fig. 8a. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
Section of outer rim of specimen shown in fig. 7a and 6a, showing some of the septa of the counter quadrants (reversed).

8b. *Lopholasma carbonaria* Grabau..... .....p. 43
Section of specimen shown in fig. 7c, about 2 mm. higher (reversed) Within the calyx a section of the smaller end of another individual.

8c. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau..... .....p. 51
Section of specimen shown in fig. 7c, about 2 mm. higher (reversed). The cardinal septum is on the right. (See text fig. 62)

8d. *Lopholasma carbonaria* Grabau..... ....p. 43
Section of specimen fig. 7d, about 2 mm. higher (reversed) (See text fig. 54)

8e. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau..... .....p. 51
Longitudinal section of a part of a corallum showing the spinous character of the carinæ with their upturned edges shown in transverse section.

Fig. 9a. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
Section of part of rim of the specimen shown in 8a, about 3 mm. higher.

9b. *Lopholasma carbonaria* Grabau..... .....p. 43
Section of the small specimen shown in fig 8b, about 3 mm. higher; on upper side of same rock slice.

9c. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau..... p. 51
Normal view of section of specimen 8c, 3 mm. higher, Cardinal septum on left. (See text fig. 63)

9d. *Lopholasma carbonaria* Grabau..... .....p. 43
Section of the specimen shown in fig. 8d, on upper side of same rock slice, about 3 mm. higher. (See text fig. 55)

9e. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau.....p. 51
Another longitudinal section apparently of the same corallum as that figured in fig. 8e, on the opposite side of the same slab 3 mm. thick, showing carinæ in transverse section.

9f. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau..... .....p. 51
Median longitudinal section of another individual showing horizontal bar-like character of carinæ in section parallel to septum; also showing stereo-columella and projecting palicolumella. (See text fig. 65) (Figs. 8 & 9, Geol. Surv. China cat. 147)

Fig. 10c. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau.....p. 51
Section of the specimen shown in Fig. 9c, about 2 mm. higher (reversed) counter septum on left. (See text fig. 64).

10d. *Lopholasma carbonaria* Grabau.....p. 43
Section of specimen shown in fig. 9d, about 2 mm. higher (reversed). (See text fig. 56).

Fig. 11c. *Lophophyllum (Lophocarinophyllum) acanthiseptum* Grabau.....p. 51
Section of part of calicinal rim of specimen fig. 10c. and about 3 mm. higher on opposite side of same rock slice. Counter septum on right, short, a section of the pseudocolumella which is free at this point, near the center. (Not well shown.)

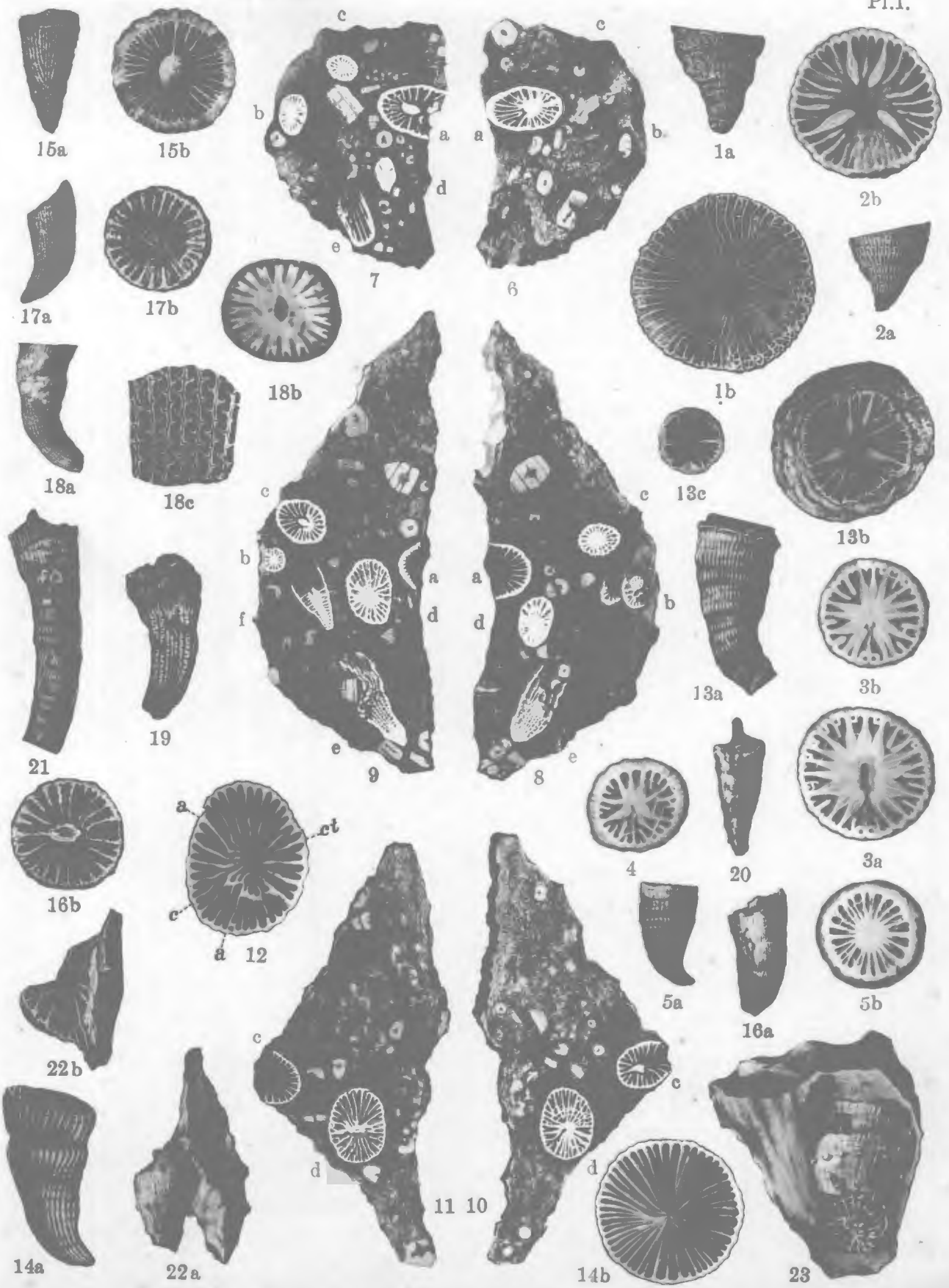
11d. *Lopholasma carbonaria* Grabau.....p. 43
Section of the specimen shown in fig. 10d, about 3 mm. higher (reversed) on opposite side of same rock slice; cardinal septum lower right-hand.
All the figures are natural size. Black Carboniferous Poshan limestone, Tung Chuang, I-Hsien Shantung. (Figs. 10 & 11, Geol. Survey of China, cat. 148).

Fig. 12. *Lopholasma carbonaria* Grabau..... ...p. 43
Section of specimen shown in fig. 11d, about 2 mm. higher (reversed), enlarged twice; c, cardinal septum; ct, counter septum; a,a, alar septa. Same horizon and locality as figs. 6 to 11. (G. S. Ch. cat. 149).

Fig. 13. *Tachylasma elongata* Grabau..... .....p. 37
a. Side view of holotype natural size.

Grabau: Palæozoic Corals of China.

Pl.I.



中國古生代珊瑚化石

13b. Upper end (polished), showing arrangement of septa a short distance below the calyx. Enlarged twice.

c. Lower end of specimen (polished) showing four strengthened septa at this stage. Enlarged twice.

Lower (?) Carboniferous limestone, Fenchen, Kiangsi province. (G. S. Ch. cat. no. 154).

Fig. 14. *Heterolasma edwardsianum* (de Koninck) ..... p. 41

a. Side view of de Koninck's type enlarged.

b. Calicynal view of same in further enlargement. Carboniferous limestone of Tournay (Dinantian) (Copies of figures by de Koninck).

Fig. 15. *Lophophyllum pendulum* Grabau ..... p. 48

a. Cardinal view of the holotype, natural size.

b. Calicinal view of same, enlarged twice. Carboniferous limestone of Yunnan (?) Geol. Surv. China, cat. no. 150.

Fig. 16. *Lophophyllum pendulum* Grabau ..... p. 48

a. Lateral (alar) view, the basal part imperfect; natural size.

b. Calicinal view (cardinal septum on right); enlarged twice. Carboniferous limestone (Dinantian?) Shih-lin Yuan, Kung Hsien, Honan, Coll. C. F. Erickson (G. S. Ch. cat. no. 152).

Fig. 17. *Lophophyllum pendulum* Grabau ..... p. 48

a. Lateral view, showing curvature, natural size.

b. Calicinal view, enlarged twice; counter septum near side of greatest curvature. Carboniferous limestone (Dinantian?) Honan. (G. S. Ch. cat. 153).

Fig. 18. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau ..... p. 51

a. Side view of a nearly complete specimen polished on the upper surface, and with sides slightly worn. Natural size.

b. Section of the same a short distance below the calyx rim showing free upper end of columella; enlarged twice.

c. A portion of the worn surface of the specimen, enlarged three times, showing the lateral carinæ of the septa. Kuantikou limestone, Taiyuanfu district (Loc. 38) Shansi. (E. Norin coll. G. S. Ch. cat. no. 155).

Fig. 19. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau ..... p. 51

Submedian longitudinal section, showing strong development of carinæ on lower part of septa.

Kuantikou limestone, Taiyuanfu district (loc. 38) Shansi. (E. Norin coll. G. S. Ch. cat. no. 156).

Fig. 20. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
View of a small specimen with strongly exert columella. Natural size. Hsiehtao limestone, Tungtayao, Taiyuanfu district, Shansi, (loc. 39) (E. Norin coll. G. S. Ch. cat. no. 157).

Fig. 21. *Lophophyllum* (*Lophocarinophyllum*) *acanthiseptum* Grabau.....p. 51
Side view of an unusually long form, incomplete at lower end, and crushed above, showing exert columella. Natural size. Hsiehtao limestone, Tung-ta-yao, Taiyuanfu district, Shansi. (E. Norin coll. G. S. Ch. cat. no. 158).

Fig. 22. *Amplexus spinosus* var *sinensis* Grabau.....p. 64
a. Side view of a fragmentary corallum attached to rock showing epithecal spines; enlarged twice.
b. Calicinal view of same showing arrangement of septa and flat tabulate floor of calyx. Enlarged twice. Chihsiashan limestone (Lower Carb.), Chihsiashan, Nanking region, Kiangsu. (G. S. Ch. cat. no. 159).

Fig. 23. *Amplexus spinosus* var *sinensis* Grabau.....p. 64
Another specimen showing septa in broken lower end, broadly expanding form, and epithecal spines. Enlarged twice. Same horizon and locality (cat. 160).

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PALÆOZOIC CORALS OF CHINA
PART I; TETRASEPTATA.

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INTRODUCTION; PETRAIIDÆ, STREPTELASMAIDÆ, AND CYATHAXONIDÆ.
PLATE I. 74 TEXT FIGURES

PEKING 1922.