行政院及所屬各機關出國報告

（出國類別:研究）

猛獁象系統分類與演化之研究暨古脊椎動物之維護

服務機關:國立自然科學博物館

出國人職　　稱:研究員

姓　　名:彭延年

出國地區:英國

出國期間:九十一年十月二十二至十一月三日

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猛獁象系統分類與演化之研究暨古脊椎動物化石之維護管理

主辦機關:

國立自然科學博物館

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程延年　國立自然科學博物館　地質學組　研究員

出國類別: 研究

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關鍵詞:　猛獁,系統分類,演化,古脊椎動物,博物館

內容摘要: 本館地質學組執行「猛獁象系統分類與演化之研究暨古脊椎動物化石之維護管理」研究案。由國立自然科學博物館地質學組研究員 程延年博士前往。應英國倫敦大學（University College London，UCL）動物暨比較解剖學格倫特博物館（Grant Museum）之邀， 於本（九十一）年十月廿一日至十一月三日前往研究。 主要參訪研究機構－倫敦大學（UCL）附設之動物暨比較解剖學格倫特博物館（GRANT MUSEUM），乃1828年由著名博物學家Robert Grant 所創設，他是第一位倫敦大學的比較解剖學與動物學教授，畢業於愛丁堡大學，深信演化理論，於1826-27年深深影響同時在愛丁堡大學醫學院修習的查理士・達爾文，爾後成爲了演化學之父。該博物館規模不大，收藏卻完整而豐富，具備了歷史的累積與傳承，成爲該校生命科學與演化學師生在教學、實習與研究上最重要的場所與資源。所收藏長鼻目（象類群）的化石與現生標本系統完整且豐富，許多歐陸模式標本得以讓研究人員親自量測，並核對。該博物館並持續執行一般科學教育普及工作，預約倫敦地區學生參訪實習，推出簡單精緻的特別迷你型展示（如近期推出生物多樣性展示），做爲回應社會大眾對博物館的期望與需求。

本文電子檔已上傳至出國報告資訊網

2002 年 11 月 5 日

教育部核定九十一年出國研究執行報告

壹、依據教育部台（九 0）人（二）字第九 0 一一四 00 八號函，核定本館地質學組執行「猛獁象系統分類與演化之研究暨古脊椎動物化石之維護管理」研究案。前往英國等地區，核定經費玖萬伍仟圓整。（附件一）

貳、執行人員，由國立自然科學博物館地質學組研究員 程延年博士前往。應英國倫敦大學（University College London，UCL）動物暨比較解剖學格倫特博物館（Grant Museum）之邀， 於本（九十一）年十月廿一日至十一月三日前往研究。（附件二）

參、研究、參訪闡述：

（一）主要參訪研究機構－倫敦大學（UCL）附設之動物暨比較解剖學格倫特博物館（GRANT MUSEUM），乃 1828 年由著名博物學家 Robert Grant 所創設，他是第一位倫敦大學的比較解剖學與動物學教授，畢業於愛丁堡大學，深信演化理論，於 1826-27 年深深影響同時在愛丁堡大學醫學院修習的查理士・達爾文，爾後成為了演化學之父。該博物館規模不大，收藏卻完整而豐富，具備了歷史的累積與傳承，成為該校生命科學與演化學師生在教學、實習與研究上最重要的場所與資源。所收藏長鼻目（象類群）的化石與現生標本系統完整且豐富，許多歐陸模式標本得以讓研究人員親自量測，並核對。該博物館並持續執行一般科學教育普及工作，預約倫敦地區學生參訪實習，推出簡單精緻的特別迷你型展示（如近期推出生物多樣性展示），做為回應社會大眾對博物館的期望與需求。

感想：博物館源起於歐陸，歐洲重要大學的相關自然科學系所，都附設有規模大小不等的博物館。尤其是生命科學系、動物系、植物系、地質學系、古生物學系與考古暨人類學系，做為教學、研究與科學教育推廣用途，在奠定自然科學基礎發展、普及與

生根的功能上，有大的助益不容忽視。唯博物館以收藏爲主軸與靈魂，以研究人員（Curator / Keeper） 爲主導角色，是百年來不變的方向。東方的博物館（台灣亦然），東施效顰，建立起宏偉的軀殼建物，討喜聳動的展示議題，扭曲偏頗的管理、行政主導之策略，失去了收藏（物件）的靈魂，與研究館員（Curator）爲核心的規制，必然走向世俗化、嘩眾取寵淺碟子的泡沫式活動。而各個博物館又難以各守本位，名實不符，又失去了自我定位（Identity）的堅持，造成了「館格錯亂」的後果。「歷史博物館」展出油畫，「人類學博物館」展出恐龍，「自然史博物館」展出敦煌，也就不足爲奇了。其長遠影響在於博物館屬性盡失，淪落爲展覽場而已，若主導者（通常是館長一人決策）再試圖與世俗掛勾，那麼博物館進而沈淪成爲世貿中心的形象就可預期。「Museum」的初衷旨義盡失，僅以招攬顧客爲本位，算計人頭做爲業績的最高指導原則。掌大權、居大位者，能不慎乎？科博館在世俗眾生中，堅持本位引領前行，殊爲艱辛不易

（二）倫敦大學動物學系（Department of Biology，UCL）——新生代長鼻目（象類群）的演化分類研究，於倫敦大學任職的 Adrian M. Lister 教授，爲國際馳名的專家。李斯特博士畢業於英國劍橋大學，並先後任職於劍橋大學與倫敦大學。本次考察研究項目，亦是與李斯特教授合作項目。國立自然科學博物館地質學組 張鈞翔助理研究員，正在倫敦大學以留職進修方式，投在李斯特教授門下，研習「遠東地區第四紀真象科的研究」，做爲博士論文一部份。作者過去四年，在國科會自然處支助下，持續進行台灣第四紀澎湖海溝動物群的研究項目。最近提出成果報告（91 年 10 月 15 日，如附件一）。李斯特教授專精於真象科猛獁象類群的研究，於 1994 年出版「Mammoths」專書，洛

陽紙貴。最近與蘇聯科學院 Andrei V. Sher 教授共同發表於【Science】重要總結性論文——長毛猛獁象（*Mammuthus primigenius*）的起源與演化（Science，294：1094-1097，Nov. 2001），是爲經典的報告，備受矚目。於參訪期間，與李斯特教授、張鈞翔博士生，共同量度澎湖海溝動物群的所稱"古菱齒象，*Palaeoloxodon* spp."標本，並仔細討論與歐陸、西伯利亞、印度、中國北方及日本相關標本所得數據差異性的演化上意義，獲得重要結論。其中，若最終證實澎湖海溝動物群的長鼻目化石，有屬於猛獁象類群的成員份子，將會是全球該類群動物分佈的最南緣，在古生態、古環境與猛獁象演化、遷徙及第四紀環境變遷上，具重大意義。正在做細節分析，並撰稿中。

經由倫敦大學的主要參訪研究機構行程，並經 Dr. Lister 之引薦，參訪下列研究機構：

（三）英國倫敦自然史博物館（NHM，London）－NHM，London 是歐陸最重要的自然史博物館，除展示、教育活動而外，豐富的收藏標本，是全球研究學者持續造訪的重要原因。其中象類化石與現生標本收藏豐富。脊椎古生物學門負責研究人員 Norman Macleod 爲美國德州大學（UT－Dallas）同門師兄弟，原以放射蟲與有孔蟲爲素材，進行演化模式研究，現偏向演化生物學方面的課題。於收藏庫房中進行系列標本的量度與照相，做爲比對用途，並提供張鈞翔博士論文的一部份。

倫敦自然史博物館，同時進行一項轟動的中國恐龍－鳥類演化特展（Dino-Birds）－中國帶羽毛的恐龍特展（18 July 2002-5 may 2003）。該館四足動物 / 恐龍學研究員 Dr. Angela Milner 負責籌展與解說訓練任務。該展示素材與沈春池文教基金會正在洽談中，擬前來台灣巡迴展的「恐龍、鳥、顯花植物與真獸類群起源」展，標本雷同並重疊。特前往先睹爲快。借予倫敦的原件標本不多（由北京中國地質博物館借展），卻都是最關鍵的化石原件，發表於【Nature】與

【Science】期刊，最轟動的正型標本，加上倫敦自然史博物館保存收藏的鎮館之寶，始祖鳥第一件標本（BMNH37001 正、負型原版化石），經過精緻、高明、神乎奇技的展示手法，烘托出這個特展主題的精髓深義，讓人不禁感受到歐陸博物館事業，與博物館工業的引領全球之勢。將全部展示錄影並數位相機拍攝，以為師法。

倫敦自然史博物館另一項重要創新大業——新近於 2002 年 9 月 30 日開幕的「達爾文中心－第一館」（Darwin Center phase Ⅰ）讓身為博物館員的我們嘆為觀止。歐陸博物館有著悠久的歷史與豐富的收藏為傲；同時更重要的是建構在「累積、傳承與創新」的共識意念下，集體共創浴火重生、鳳凰展翅的一再呈現，讓世人驚艷。達爾文中心，是一座嶄新的建物，容納著超過二千二百萬件的動物標本，於七層樓面的收藏庫房（其中包括 20 萬件的爬行/兩生動物標本；2 百萬件魚標本，2 百萬件軟體動物標本；3 百萬件甲殼動物標本）。同時容納相關的工作室、實驗室、研究室。更重要的是將部份收藏庫房，以半隔離方式展現在一般觀眾眼前，並透過預約參訪的方式，與研究人員面對面討論方式，及透過英國 BBC 電視台同步影像，顯示技術人員處理標本工作情況，讓這一批所稱「大自然的寶物」能呈現在一般觀眾眼前，打破傳統收藏、研究工作隱身幕後、壁板深處象牙塔中孤芳自賞的情境，在完整配套措施與館員共識信念之下，以及社區群眾推波助瀾激勵下，順應時代潮流，讓博物館再度活化，成為活生生的學習場所，而非冰冷的停屍間。這種突破、膽識與付諸實施的大氣魄、大手筆讓舉世爭相仿效借鏡。第二館（phase Ⅱ）擬定於 2007 年開放（面積二倍有餘，容納博物館昆蟲與植物的收藏標本，大約有 2 千 8 百萬昆蟲，與 6 百萬植物標本）。參訪歐陸博物館，最大的震撼與驚心之處，不在於他們眼前呈現的驚人表相（不論展示、建物、科學活動），而是在於它們中、長程持續不懈的發展方向與策略之擬定、討論、定

調，並逐步付諸實施。人無遠慮，必有近憂，博物館亦然。博物館的領導，高瞻遠矚，耐性十足，心胸開闊，識見卓越，容棄土而納百川；館員自然望風披靡，同心協力，共享榮耀。鎂光鐙下，沒有主角的秀場，祗有觀眾的讚賞，與館員（Curator）的滿心喜悅。回望台灣博物館界龍頭大老或者後起之秀，能得其真傳者，直如稀有動物鳳毛鱗角，能不嘆乎。科博館一路走來，有著英明領導指引明燈，實屬萬幸。

（四）劍橋大學 Sedgwick 博物館（地質古生物學），動物學博物館（動物學）與人類學博物館（考古學）－爲檢視並比對相關化石與現生骨骼標本，劍橋大學的 Sedgwick 博物館是最古老的博物館，始於 1728 年 John Woodward 博士所創立，以地質學著名學者 Sedgwick 博士之名爲名，珍藏超過一百萬件化石標本，包括一些歐陸重要長鼻目化石的模式標本。（同時該館也珍藏達爾文所採集重要的岩石、化石標本）該博物館爲典型的傳統式，櫥櫃陳列（cabinet）博物館，主要以研究與教學爲主。動物學博物館與生物學系關係密切，於 2001 年 10 月經過完全整修展示、收藏空間後，重新開放。收藏物件從 1814 年開始，歷經 2 個多世紀，涵括各類現生動物骨骼復原裝架、浸液標本以及少數化石動物標本。經量測現生象骨骼標本，用以比對。人類學博物館乃座落於鄰近 Downing Street，順道造訪，除考古學物件外，尚有民族學收藏甚爲可觀。

（五）參訪其間，轟動英倫的「人體世界，Body World」特展——真實人體解剖構造特展於倫敦 Atlantis Gallery 展出。該展示是由德國醫師 Gunther von Hagens 教授，經由精心設計、製作而成的真實人類體軀（包括骨骼、神經、器官、軟體組織與切片）經由特殊置換技術而呈現。表現方式真實、生動、戰慄而驚心。在網路上持續受到讚揚與責難，全然兩極式的評價。該展示中幾件主要物件（main pieces），包括奔跑、打藍球、皮膚－器官肌肉－骨骼三層剝離，尤其是孕婦懷胎

而死的解剖，最受爭議。衛道之士，大加撻伐，這也是這項展示在歐洲，迄今未能進入自然史博物館堂奧的理由。歐洲返回，在十一月廿日，該位醫師在展示場子中，更大膽的挑戰世俗舉行了一次售票現場解剖的劇碼（這一場純然是作秀成份居多），爲英國 170 年來首次公開場合的人體活體解剖。報章雜誌大肆報導、電視媒體現場轉播。頃聞，該項展示的部份展品，將引進台灣博物館展出，宜深思熟慮。僅以面相的提倡科學教育，解剖學的復興，對解剖構造設計（Baüplane）的理解等等理由，若難以掩飾背後淺層的譁眾取寵，爭取人潮目的，則不爲上策。本次針對長鼻目系統分類及演化研究部份，報告如上。針對古脊椎動物化石之維護管理與相關展示，陳列議題部份，則順道造往訪歐陸德國南部，參予一項重要古生物化石展示會，並考察數個重要古脊椎化石博物館，略述如次：

（六）德國墨尼黑化石展示會（Munich Show）——爲全球三大化石展示會之一，本年爲第 39 屆（意即連續舉辦近 40 年），於墨尼黑近郊世界貿易中心舉行，展示場共陳列於三棟建物內，堪具規模，參予廠商數千家，參展歐陸博物館共十餘間，涵括重要脊椎動物化石，無脊椎動物化石、寶石、礦物與相關展示。該項展示會每年於十月期間在墨尼黑舉行，全球重要博物館研究人員（Curator）或委託專業人員（Contractor）均參與盛會，並有例行學術 / 科普研討、發表會。本年最重要議題爲德國索倫候芬（Solnhofen）地區，發掘著名始祖鳥地層，首次發現奔龍類古脊椎化石一件（尚在清理中），與中國白堊紀早期熱河動物群中，轟動世界的帶毛恐龍一奔龍類（現正在倫敦自然史博物館展示中），極爲神似。引起全球古生物學家廣泛注意。

（七）德國斯圖佳附近，Holzmaden 動物群（侏羅紀早期）的古脊椎動物專業化石博物館（Urwelt-Museum Hauff）。該博物館爲一小型、地區性、專業性（純然侏儸紀早期 Holzmaden 動物群收藏。修復、展示、交易、

交換）的博物館。爲祖孫三代承襲經營，卻是收藏有全世界最著名、最重要的海棲爬行動物（魚龍、蛇頸龍爲主）以及著名的鯊魚、鰻類、翼龍、腔棘魚、箭石、菊石、海百合等化石。一個私人設立、經營的博物館，其常設展示卻出乎意料之外的精緻、生動與深入，深深反應一個國家文明的指標騰昇。

（八）德國索倫侯芬（Solnhofen）博物館－該博物館座落於山丘上一座古老城堡式建物之中，爲當地的地標型建物。館內收藏即爲舉世聞名、侏羅紀晚期（大約 155-150^{myb}）包括始祖鳥、美頜龍在內的 Solnhofen Lagerstatten 動物群。習稱爲 Jura-Museum。館長親自帶領解說展示，並討論與中國遼西熱河生物群，時代稍晚（白堊紀早期，大約 126-135^{myb}），包括孔子鳥、長城鳥、奔龍類、帶毛恐龍群的比較；並探討交換標本之可行性。這一座歷經世紀以上的博物館，面臨經營上經費籌措的困境。

（九）德國法蘭克福自然史博物館（Senkenberg Museum）——該博物館爲典型的自然歷史博物館，規模中、大型，有龐大的研究團隊與收藏標本，造訪該博物館研究人員，主要有兩群極爲珍貴的館藏：爲長鼻目的收藏與展示。從最早期始祖象，到恐象、嵌齒象、稜齒象、劍齒象，乳齒象、猛獁象到現生非洲象與亞洲象的骨骼復原裝架標本，一應俱全。除量度部份重要更新世象臼齒標本外，並拍照部分典藏化石，作爲日後比對之用。第二部份爲新生代始新世，舉世聞名的油頁岩埋藏 Messel 動物群。這個動物群的化石埋藏、發掘、整修，與復原有世紀以上的歷史，涵括現代型重要的生物群落，與中國山旺動物群（中新世）可相互比對。山旺動物群埋藏在同樣特殊的硅藻岩層中，至今未能妥善處置，以致化石經長久收藏，崩解而損傷甚而遺棄。而 Messel 的化石，經特殊原址封存技術，雖然化石被全然壓扁幾成二度空間平面保存，細緻構造依然保存，供給研究與展示。對德意志共和國傳統

幾個世紀修復大自然瑰寶之用心、尊重極爲感佩。

（十）索倫侯芬灰質泥板岩礦區－在歐洲三大重要化石產地（即侏羅紀早期的侯斯瑪登化石群；德國侏羅紀晚期的索倫侯芬化石群與新生代始新世的梅索動物群），唯一持續開採的，就只剩索倫侯芬灰質泥板岩礦區三處。目前都由土耳其裔德人開採，主要挖掘建材裝飾用石板，珍貴化石反而成爲了附屬品。與當地礦主商議，進入露天礦區，在冷風中發掘，夢想發掘到；第九件的始祖鳥標本。這片厚僅數十公尺，呈水平分佈數百公里的鈣質灰岩，薄層呈板狀，受後期帶錳的水溶液浸染、結晶，在層面上呈松枝狀，黑色的軟錳礦（dendrite）聚叢，極爲漂亮。化石層侷限在少數層面呈富集狀態，其它薄層則零星分佈。挖掘多時，出現最普遍的魚類、龍蝦類及少數昆蟲標本。

肆、 感想與建議：

（一）脊椎古生物學源起於歐陸。從比較解剖學大師居維葉（Cuvier ）的創立引領，到歐文（Richard Owen）創建倫敦自然史博物館。歐洲的古生物學有著悠久的歷史傳承、根基深厚，欲窺堂奧，應鼓勵學子前往考察研習。

（二）博物館起源於歐陸。從舉世聞名的大英博物館系統，到法國自然史博物館系統，到德國柏林博物館，Senkenberg 博物館，到蘇聯列寧格勒博物館；到爲數成千的小型、地方性、私人專業博物館。精緻、專業、用心與堅持傳統，在世俗狂瀾下依然堅守本職與使命，歷經世紀而不改其初衷，相對亞洲各國博物館事業，平地建高樓，在領導統御、收藏核心，研究群靈魂，與「專業」界定、堅持的各項指標中隨風飄搖，遇俗則媚，無能建構可長可久的制度章法，人去政息；新人上任，另起爐灶，以「常識」引領，昂首闊步；與「博物館，Museum」初衷旨義漸行漸遠。成爲了一盞又一盞乍現乍滅的明燈、舵手與標桿，而博物館事業與工業卻載沈載浮，航向未知的迷茫。

（三）針對特定議題的研習（考察學習），宜編列預算，結合較長時間（半年以上），較深入探究，有計劃、有系統的培養潛在人才。而非散彈打鳥、權力下放雨露均沾式的蜻蜓點水。如此累積，不同議題有不同潛在人力庫，可做爲爾後「假以時日必成大器」的可用之才。否則，年復一年，領導班子依舊是身居要津，既非天縱英明不可一世，亦非魅力十足望風披靡，也非胝手胼趾身先士卒者。「常識」無足以引領「專業」的事業，想當然爾的直觀，僅是曇花一現的驚艷。

（四）行政院持續投注經費，支持（支助教育部、文建會等機構），對所屬館所自行設定議題之出國研習、考察，是高瞻遠矚的策略。如何進而落實中、長期系統性、完整性議題的設定、策略的鎖碼，關鍵在於有識見、有判斷、有遠見的“委員會”，經過深思熟慮擬定出務實的一個方向與綱領，與相關館所認真的共謀識見，彙集共識，訴諸文字，照表操課，追蹤考核，日起必然有功。

（五）在職進修管道的精準疏通。精準者，意謂針對議題，慎選人才，全力支助。疏通者，不侷限於留職停薪，自謀財力，自生自滅。既避免散財童子的作風，亦避免培育之才無能爲用之浪費。關鍵，在每個機構自我定位(identity)，發展策略（strategy），使命認知與堅持，能夠護持著「累積－傳承－創新」三把薪火，一脈相傳。

伍、經費：本計劃申請並經核定經費玖萬伍仟圓整。全部執行費用，包括運輸（飛機、地鐵、快速鐵路、公車等），住宿、飲食，參觀門票等（細目如附件）。不足部份，自行支付。

陸、附件（含核定文件、邀請函件、影像記錄、經費核銷等，如附）。

出差報告人　程延年

國立自然科學博物館
地質學組 研究員
古生物學門負責人
2002 年 12 月

附件：經費核銷細目（超支部份自行支付）

核定經費：新台幣玖萬伍仟圓整（95,000.00）

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UNIVERSITY COLLEGE LONDON
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GRANT MUSEUM OF ZOOLOGY AND COMPARATIVE ANATOMY

24/07/2002

Dr. Chen, Yen-Nine
Curator of Palaeontology
Division of Geology
National Museum of Natural Science
1, Kuan Chien Rd., Taichung 404, TAIWAN
Tel: +886-4-23226940 ext 614
Fax: +886-4-23231730
e-mail: joe@mail.nmns.edu.tw

Dear Dr. Chen,

It is with great pleasure that I invite you to Grant Museum of Zoology, University College London to study our elephantid fossils. I am happy to confirm that your visit will take place in October 2002 and look forward to meeting you then.

Please do not hesitate to contact me if you require any further information,

Yours Sincerely,

Dr. Helen Chatterjee
Curator, Grant Museum of Zoology

國立自然科學博物館

擬辦：一、本件係九十一年度因公派員出國計畫業奉行政院核定之案。

二、本館計二件獲核定，分別為展示組之第三屆科學中心世界論談壇及地質學組之猛獁象係統分類與演化之研究暨古脊椎動物化石之維護管理。

三、擬會請相關組室依規定辦理，文陳閱後存查。

敬會

地質學組

展示組

會計室

研究助理 王士偉

動物學組 助理研究員 張鈞翔

人事室 主任 陳朝山

約聘助理員 李怡

教育部　函

機關地址：台北市中山南路五號
傳　　真：〇二-二三九七六九四六、〇二-二三九七七〇二二
承 辦 人：甘玉慈
聯絡電話：〇二-二三五六五九三七

受文者：如正、副本

地　址：
速別：最速件
密等及解密條件：
發文日期：中華民國九十年八月二十七日
發文字號：台（九〇）人（二）字第九〇一一四〇〇八號
附件：

主旨：本部暨所屬機關學校九十一年度派員出國考察、訪問、出席國際會議、競賽計畫及出國進修、研究、實習計畫，業奉 行政院核定如附件，請 查照。

說明：

一、依行政院（九十）年八月八日台九十教字第〇四五五四一號函辦理。

二、公務單位部分所需經費於本部暨所屬機關學校九十一年度歲出之國外旅費額度範圍內檢討核定（如附件），非營業基金單位所需經費於行政院核定國外旅費額度範圍內列支。

三、檢送本部暨所屬機關（公務單位）九十一年度派員出國（訪問、考察、會議、競賽及研究、實習）計畫表（核定本）、本部所屬機關學校（非營業基金單位）九十一年度派員出國（訪問、考察、會議及進修、研究、實習）計畫表（核定本）各一份。

四、本案公務單位出國研究、實習部分，請確依「公務人員出國進修研究實習要點」及「行政院及所屬各機關出國報告綜合處理要點」規定辦理。

正本：本部各單位（含中部辦公室）、部屬機關學校
副本：本部會計處、人事處（均含附件）

部長 曾志朗

裝　訂　線

教育部暨所屬機關學校（公務單位）

九十一年度派員出國（研究、實習）計畫表（核定本）

單位	區分	計畫名稱	擬前往國家或地區	天數	人數	備註	金額（單位：千）
教育部	研究	海事教育（北歐）進修研究	英、荷	一個月	1	技職司	100
國立虎尾農工	實習	多元智慧理論在技職教育上的應用	美國	一個月	1	部屬學校	100
國立歷史博物館	實習	培植修護人員專業技術	美國	60 天	1	部屬機關	95
國立自然科學博物館	研究	猛 馬象系統分類與演化之研究暨古脊椎動物化石之維護管理	英國	一個月	1	部屬機關	95
國立科學工藝博物館	研究	博物館運用科技遺址結合當地產業文化特色之展示設計研究	英國	10 天	1	部屬機關	100
國立海洋生物博物館	實習	大型水族生物博物館給排水及廢水處水系統操作實習	日本	10 天	2	部屬機關	95

金額合計=585

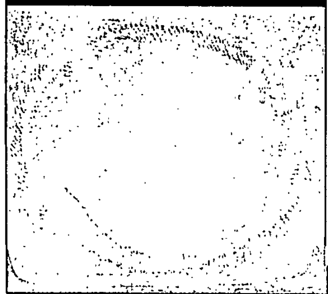
... Quaggas are a type of zebra which have been extinct for over 100 years. You can see a rare skeleton of a quagga in the Grant Museum – it is one of only six in the world! Other exotic animals include an Indian rhinoceros, a giant anteater, an anaconda snake and a tiger.

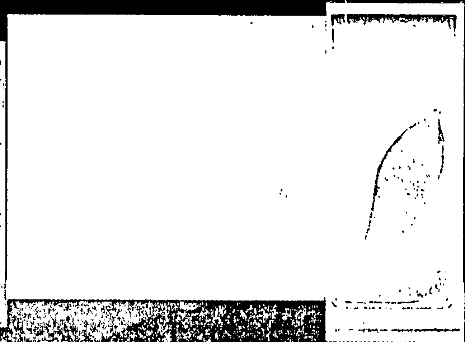
NAMED IN HONOUR OF ITS FOUNDER, PROFESSOR ROBERT EDMOND GRANT ...

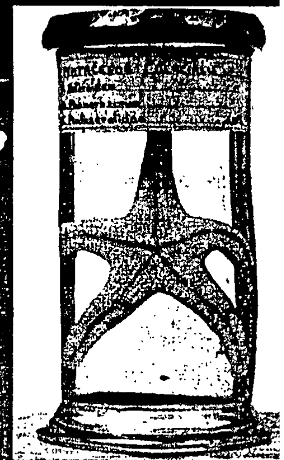
Grant was one of the pioneers of evolutionary theory and taught the young Charles Darwin. He was appointed the first Professor of Zoology and Comparative Anatomy in Britain at UCL, in 1828. In the same year Grant founded the Museum. He was probably the first person to teach evolution, twenty years before the publication of Darwin's 'Origin of Species'.

ONE OF THE OLDEST NATURAL HISTORY MUSEUMS IN BRITAIN ...

Dating back to 1828, the museum houses a diverse natural history collection covering the whole of the animal kingdom. Retaining an air of the avid Victorian collector, the museum contains cases packed full of skeletons, mounted animals and specimens preserved in fluid. Many of the species are now endangered. The museum houses many rare and extinct animals including the marsupial wolf or thylacine, and the dodo.

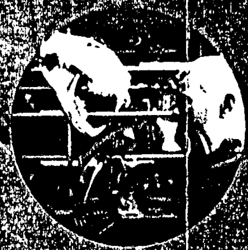






AN EDUCATIONAL RESOURCE ...

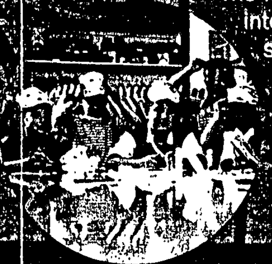
The Museum has always been used as a teaching and research resource, and is committed to encouraging the public understanding of science. We welcome school children of all ages, as well as students, researchers and special needs groups.



BY PRE-ARRANGEMENT, WE CAN OFFER ...

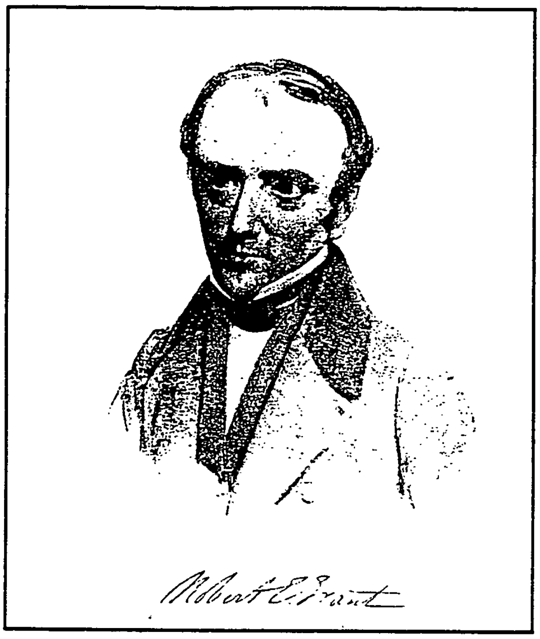
- 'hands-on' sessions
- museum based lessons
- special activity days

The Museum is especially interested in encouraging science and art classes from all age groups, since we can offer focused curriculum-based learning a stimulating environment.



GRANT Museum

The Grant Museum: History



Robert Grant, who founded the Grant Museum of Zoology, was born and raised in Edinburgh, where he attended university, gaining a degree in medicine. It was his work in marine biology, however, that gave him international acclaim, in particular his work on sponges, sea pens and molluscs. Grant was known as a committed believer in evolutionary theory, and in 1826-7 had profoundly influenced the intellectual development of the young Charles Darwin, then also studying medicine at Edinburgh.

Grant was the first professor of comparative anatomy and zoology, joining UCL when it first opened in 1828. Given his radical beliefs, it is likely that he was the first professor to teach evolutionary theory in a British university. When he arrived, he found that there was no teaching material for him to use, so he started to amass specimens, material for dissection and lecture notes. These formed the basis of the museum.

Grant remained a professor at UCL for the rest of his life. Shortly before his death, in 1874, he was persuaded by a colleague to bequeath his considerable collection of books, journals and natural history specimens to the College. This ensured that successive generations of students would have access to his knowledge.

Over the next hundred years, successive professors in the department added their knowledge and objects to the collection. For example, Sir Edwin Ray Lankester did much to improve the collection of Cephalopod material in the 1870s, and his Limmulus specimens are still in the collection today.

As the collection grew in size the issue of space became increasingly important. Over the years the Museum has moved premises several times, sometimes with major problems. In the 1880s several specimens were destroyed when part of the ceiling collapsed; the 1890s saw regular flooding; and in the 1970s the roof was completely missing! Space is still an issue today, of course, as it is everywhere in UCL, but the collection has been reorganised significantly over recent years.

&bnsp

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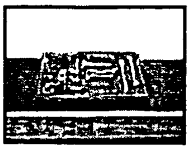
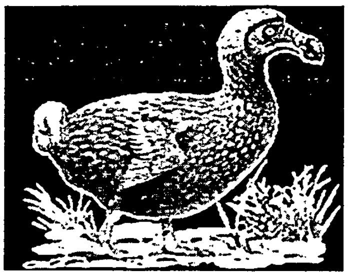
The Grant Museum - Highlights of the Collection

Note: smaller images are shown as thumbnails, double-click any image to see a larger picture

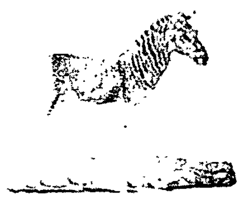


Dodo bones (*Raphus cucullatus*).



This box contains most of the skeleton of one individual animal and some additional remains. The Dodo was a flightless bird which lived in Mauritius, an island in the Indian Ocean. It is a member of the pigeon family. In the 1640s the island was heavily colonised by the Dutch, who introduced many new animals to the region. It was a mixture of the interference of these animals and the constant use of the dodos for food that led to their rapid extinction. By the 1690s the last known Dodo had disappeared.

Skeleton of a Quagga (*Equus quagga*).



This specimen of a Quagga is extremely important for the Grant Museum because only half a dozen skeletons are known to exist in the whole world. The Quagga is a type of zebra that lived in South Africa. As this picture shows it has different colouring from the more common black-and-white Burchell's zebra, and its unusual colouring was one of the reasons why the species became extinct in the 1870s. Hunters and European settlers killed the Quaggas in large numbers to make grain bags and because the skin was such an unusual colour and pattern.

Skeleton of a thylacine (*Thylacinus cynocephalus*)

The Thylacine, also known as the Tasmanian Wolf, was a large marsupial carnivore that lived in Australia and New Guinea. After European settlement of the country, however. numbers of Thylacine began to fall because of hunting and loss of habitat. Many were shot by landowners because the Thylacine preyed on chickens and sheep. They were seen as such a pest that from 1888 to 1912 the Tasmanian government even offered rewards to those who brought the head of a Thylacine . By 1936 a law was passed to protect the species, although it was too late, and the last known captive animal died that year.

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UCL
COLLECTIONS

Welcome
Visitors
Friends
History
Highlights
Teaching
Outreach
News
Links
Search

Splash

Archaeology
Art
Egyptian
Geology
Science
Zoology

UCL Web

The Grant Museum: Teaching and Research

The museum has always been used as a teaching and research resource, and it is committed to encouraging the public understanding of science. The museum collections are used weekly within the college for undergraduate teaching, and for a wide range of postgraduate research. Current research areas include: Phylogeny and biogeography of gibbons (Hylobatidae) & Dental function and variability in elephants. The following departments all utilize the collections for teaching and research on a regular basis;

- Biology
- Anthropology
- Anatomy
- Geology
- History of Science
- Institute of Archaeology
- Slade School of Fine Art

Research use of the collection from the academic community outside UCL is also encouraged. One way this is being achieved is through a computer documentation programme whereby the entire collection will be accessible via the web.

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Print Back Top Home

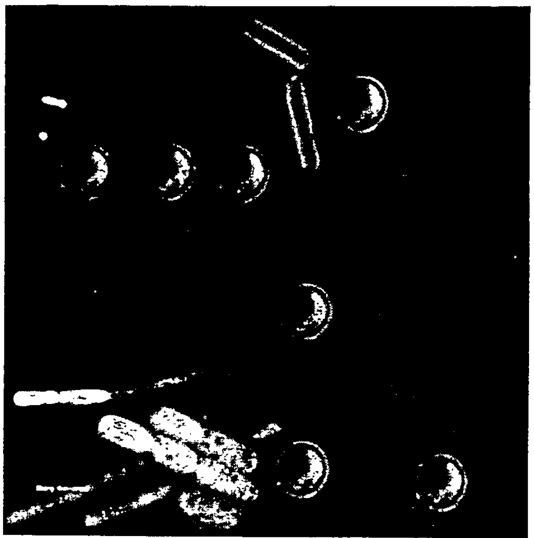
Department of Biology
UCL University College London

Research

Biology Home Page

Staff web pages by research area
See also: Staff List; Graduate Research

With links to individual research groups.



Fluorescence micrographs of cyanobacteria, by Mary Sarcina.
Contact Dr Conrad Mullineaux for details

Molecular cell and developmental biology

Cytoskeleton and Cell Cycle Research Group (Professor Jeremy Hyams)
Molecular Nociception Group (Professor John Wood)
Molecular Cell Biology of Intracellular Protein Targeting (Prof. Chris Danpure)
Development of the Nervous System (Professor William Richardson)

Ecology and Evolution

Aquatic Biology (Dr Roger Wotton)
Centre for Ecology and Evolution
Centre for Research into Ageing
Genes, Lifespan and Ageing in Nematodes (Dr David Gems)
Genetics and Evolution of Reproductive Traits (Dr Tracey Chapman)
Genetics of Fitness-Related Traits (Professor Linda Partridge)
Grant Museum of Zoology
Insects, Sex and Parasites (Dr Greg Hurst)
Molecular Evolution and Systematics (Dr Ziheng Yang)
Population Genetics of Mimicry, Speciation and Conservation (Dr James Mallet)
Sex, Genes and Evolution in Stalk-eyed Flies (Dr Tracey Chapman, Dr Kevin Fowler, Dr Andrew Pomiankowski, Dr Hazel Smith)
Social Evolution Research Group (Dr Jeremy Field)

Human and Population Genetics

Centre for Genetic Anthropology
Centre for Human Genetics
Human Molecular Genetics (Dr Andrés Ruiz Linares)
Centre for Population Genetics and Human Health (Professor David Goldstein)
Mucins and Lactase (Professor Dallas Swallow)

Plant Biology and Microbiology

Glynn Laboratory of Bioenergetics (Professor Peter Rich)
Molecular and Physiological Ecology Laboratory (Dr John Pearson)
Molecular Plant Physiology (Dr Astrid Wingler)
Photosynthesis Research Group (Professor Mike Evans, Professor Jonathan Nugent, Professor Peter Rich, Dr Saul Purton, Dr Conrad Mullineaux)

Plant Pathology (Dr Richard Strange)

Other Research Information

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Need a research job? Advice for finding a job
UCL positions available
Postgraduate Students
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Biology Home Page
About Biology at UCL

Department of Biology
University College London

Biology home page

About the Department; In pictures

Research in the Department
Including interdepartmental centres and institutes

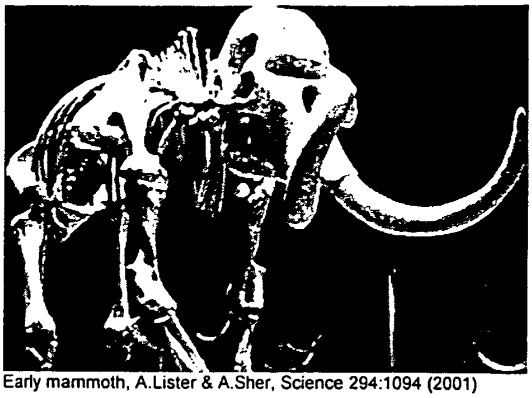
What's on
Biology seminars, department news

For current BSc students; course information
Department services, documents, courses

Admissions for BSc students
Information for prospective BSc students: Biology, Genetics and Human Genetics (including zoology, plant science, molecular biology, microbiology, evolution, conservation)

Graduate students,
Postgraduate studies, PhD information, MSc courses etc.

Staff
Fellows, academic and other staff, staff web pages and projects



Early mammoth, A.Lister & A.Sher, Science 294:1094 (2001)

Contact details; Admin; Positions available etc.

Where are we? - maps, directions, and delivery details. Safety and procedures, computer, internet & web support. Jobs available.

The Grant Museum
A museum of zoology

Overall Index

Department of Biology, University College London, Gower Street, London WC1E 6BT UK
tel: +44-20-7679-7098. fax: +44-20-7916-7096. Email Biology.

Department of Biology
University College London

Biology Home Page

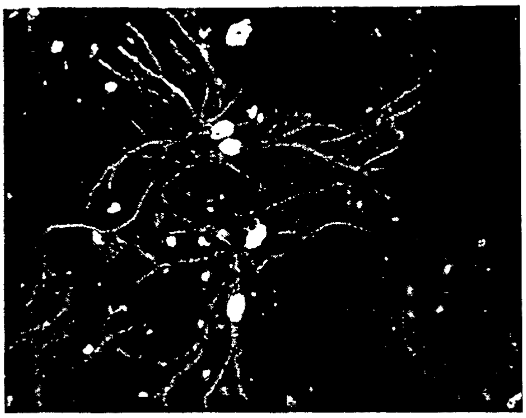
History
The Department of Biology was formed in 1987 by a merger between former Departments of Zoology & Cell Biology with Botany & Microbiology. In 1995 the Department of Genetics & Biometry was added (see The Galton Laboratory).

Today
We now have about 30 academic staff, 10 senior research fellows, 55 research staff, and 50 full-time and 10 part-time PhD students. We are also the home department for about 40 more PhD students based at a number of external institutions such as: the Imperial Cancer Research Fund, the National Institute for Medical Research, The Natural History Museum, Rothamsted Experimental Station, and the Institute of Zoology.

Research in the Department of Biology was rated internationally excellent (5) in all three of the 1992, 1996 and 2001 Research Assessment Exercises. Research income is in excess of £4 million per annum; this money supports internationally recognised research programmes in the following areas:

- Cell biology
- Developmental Biology
- Evolutionary Biology
- Human Genetics
- Plant Biology and Microbiology

The Department was also awarded the maximum score of 24/24 in its Teaching Quality Audit in March 1999.



Immunofluorescence micrograph of a nerve cell culture. The large red cells are astrocytes. [Bill Richardson]

Undergraduate and Master's teaching
We contribute to teaching an MSc in Conservation. About 300 undergraduates take our BSc degrees in Biology, Genetics, and Human Genetics, each with many options and courses in Conservation, Ecology, Evolution, Cell Biology, Developmental Biology, Genetics, Microbiology, Molecular Biology, Zoology and many others.

Facilities
In addition to its main sites in the Darwin Building and Wolfson House, the Department has its own field station at Blakeney Point in Norfolk and houses its own Museum of Zoology. In addition, we have a close working relationship with a Medical Research Council research institute that located on the UCL campus, the MRC Laboratory for Molecular Cell Biology.

Message from the Head of Department
I hope these pages will give you a feel for the many exciting things happening in one of the leading biology departments in the UK.

Professor William Richardson
Head of Department

Biology Home Page

UCL COLLECTIONS

Welcome
Visitors
Friends
History
Highlights
Teaching
Outreach
News
Links
Search

Splash

- Archaeology
- Art
- Egyptian
- Geology
- Science
- Zoology

- UCL Web

Outreach Activities and Animals Loan Box

The museum welcomes school children and special needs groups of all ages. By pre-arrangement with the museum curator we can offer school groups a variety of "hands-on" sessions, museum-based lessons, and special activity days. The museum is especially interested in encouraging science and art classes, from all age groups, since we are able to offer focused learning in a stimulating environment. In recent years the museum has been undergoing a period of re-display, geared towards enhancing the interpretation of the diversity of animals in the collection, highlighting important issues such as wildlife conservation.

As part of its education outreach programme the Museum has introduced an Animals Loan Box for schools. Containing 16 original specimens from the Museum's extensive collection, the Loan Box is available to schools for use during teaching sessions.

This is a unique opportunity for pupils to learn from handling and examining closely animal remains. The accompanying Teachers' Pack is specifically targeted at KS2 and focuses on biodiversity. It includes a range of activity sheets for individual, group and class work and animal fact sheets relating to the objects in the box. The topics covered relate to the National Curriculum for science and include nutrition, conservation, food chains and animal variation and classification. Further suggestions for cross-curricular activities are provided on computer disc.

The Loan Box is available to schools for two weeks at a time. Three or four weeks advance booking is advisable.

For more information and availability contact the Museum's curator;

Helen Chatterjee (h.chatterjee@ucl.ac.uk)
Tel: 020 7679 2647
Fax: 020 7679 7096

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Geological Sciences Collections

COLLECTIONS

Intro
Visitors
History
Education
Gallery
J-Lavis
Puzzles
Micropalaeontol.
Planetary
Contact
News
Links
Search

Splash

- Archaeology
- Art
- Egyptian
- Geology
- Science
- Zoology

- UCL Web

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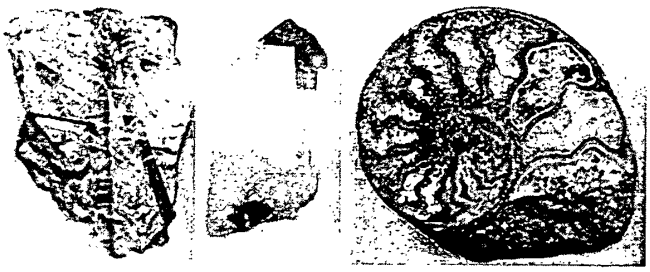
The collection contains a wealth of rocks, minerals and fossils collected from all over the world during the last 150 years. Primarily a teaching resource, some of the 40,000 specimens are on show to the public. One of the highlights is the Johnston-Lavis volcanological collection of minerals, rocks, photographs and gouaches, collected from about 1880-1912. The collection also contains the NASA archive of hundreds of thousands of images housed in the new Planetary Suite, and the internationally important micropalaeontological collections.



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Print Back Top Home

UCL
COLLECTIONS

Welcome
Visitors
Friends
History
Highlights
Teaching
Outreach
News
Links
Search

Splash

- Archaeology
- Art
- Egyptian
- Geology
- Science
- Zoology

- UCL Web

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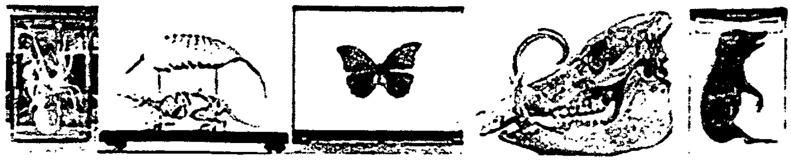
Grant Museum of Zoology And Comparative Anatomy



" As a teaching and research collection, the Grant Museum of Zoology aims to preserve and enhance the specimens in its care so that they can be used to communicate and increase the knowledge, understanding and enjoyment of natural history. "

Dating back to 1828, the museum houses a diverse Natural History collection covering the whole of the animal kingdom. Retaining an air of the avid Victorian collector, the museum contains cases packed full of skeletons, mounted animals and specimens preserved in fluid.

A · H · R · B
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Print Back Top Home

BECOME A FRIEND OF THE MUSEUM AND ADOPT A SPECIMEN ...

"There's more to life than molecules: come to the Grant Museum to see giant snails, the orang that hugged HG Wells, and more. Biology as it was, and, with luck, soon will be again!"

Professor Steve Jones, UCL

The Friends programme helps to fund ongoing projects including conservation, documentation and the renovation of the Museum displays. Funds raised through the Friends Programme enable new and exciting projects to be initiated, such as those geared to the public and schools.

Friends receive a number of benefits including:

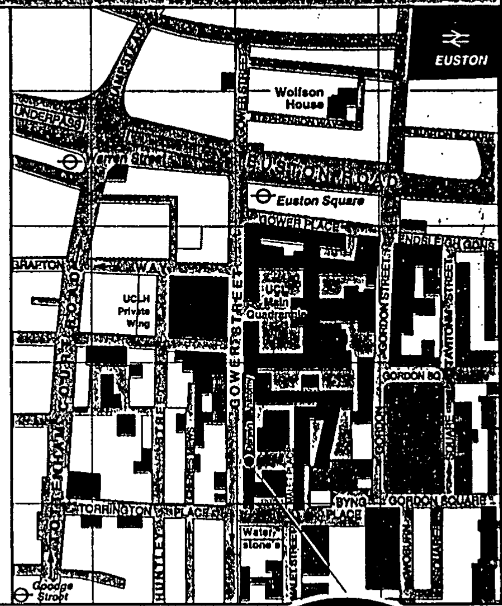
- the opportunity to adopt a specimen
- priority access to the collection
- attendance of lectures and seminars
- the opportunity to participate in special activity days and outings to places of historic and scientific interest

HOW TO FIND US ...

RAIL
Euston

UNDERGROUND
Euston, Euston Square, Warren Street, Russell Square, Goodge Street

BUSES
Euston Road: 10, 14, 14A, 18, 30, 73, A2
Gower Street: 10, 14, 14A, 24, 29, 73, 134
Tottenham Court Road: 10, 14, 14A, 24, 29, 73, 134



OPENING HOURS
Wednesdays and Fridays
1pm to 5pm.
(Appointment only at other times)
ADMISSION IS FREE

CONTACT DETAILS
For more information about the Grant Museum, the Friends Programme or our outreach activities, contact the Curator at:

Grant Museum of Zoology
Darwin Building
Department of Biology
University College London
Gower Street
WC1E 6BT
Tel: 020 7679 2647
Fax: 020 7679 7096
Email: zoology.museum@ucl.ac.uk

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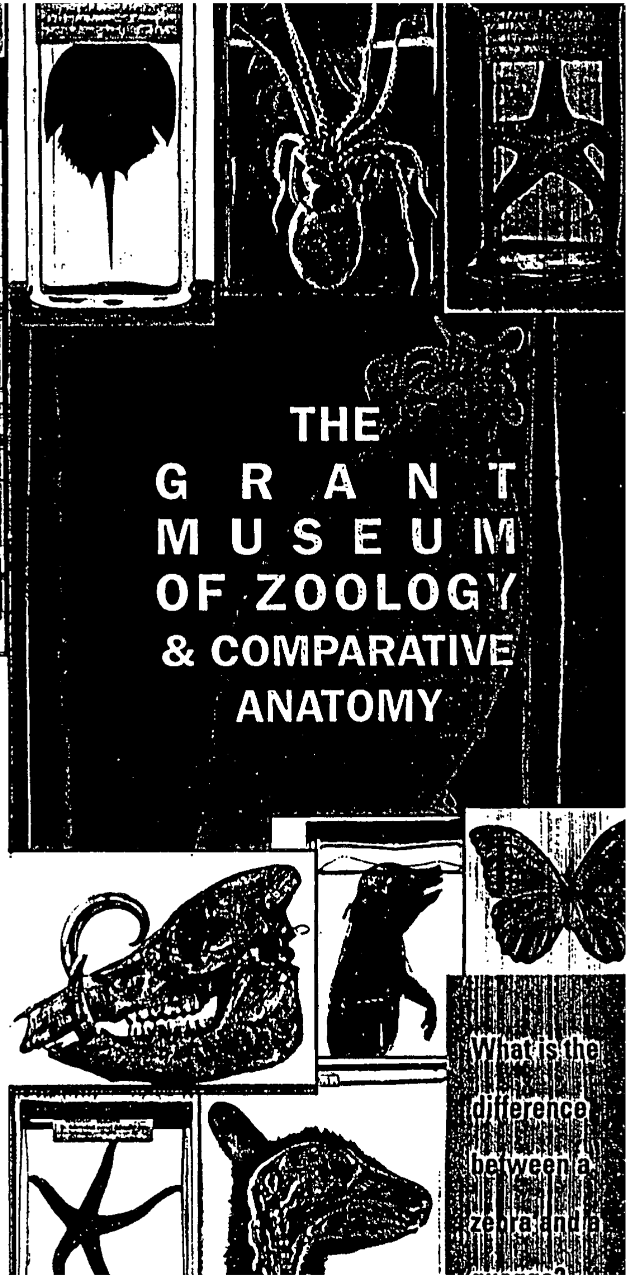


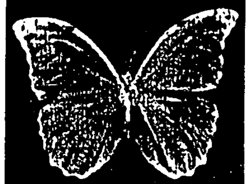
… Quaggas are a type of zebra which have been extinct for over 100 years. You can see a rare skeleton of a quagga in the Grant Museum – it is one of only six in the world! Other exotic animals include an Indian rhinoceros, a giant anteater, an anaconda snake and a tiger.

NAMED IN HONOUR OF ITS FOUNDER, PROFESSOR ROBERT EDMOND GRANT …

Grant was one of the pioneers of evolutionary theory and taught the young Charles Darwin. He was appointed the first Professor of Zoology and Comparative Anatomy in Britain at UCL, in 1828. In the same year Grant founded the Museum. He was probably the first person to teach evolution, twenty years before the publication of Darwin's 'Origin of Species'.

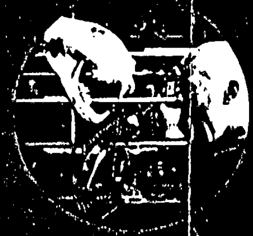
ONE OF THE OLDEST NATURAL HISTORY MUSEUMS IN BRITAIN …

Dating back to 1828, the museum houses a diverse natural history collection covering the whole of the animal kingdom. Retaining an air of the avid Victorian collector, the museum contains cases packed full of skeletons, mounted animals and specimens preserved in fluid. Many of the species are now endangered. The museum houses many rare and extinct animals including the marsupial wolf or thylacine, and the dodo.



AN EDUCATIONAL RESOURCE …

The Museum has always been used as a teaching and research resource, and is committed to encouraging the public understanding of science. We welcome school children of all ages, as well as students, researchers and special needs groups.



BY PRE-ARRANGEMENT, WE CAN OFFER …

- **'hands-on' sessions**
- **museum based lessons**
- **special activity days**

The Museum is especially interested in encouraging science and art classes from all age groups, since we can offer focused curriculum-based learning in a stimulating environment.

n photography by Fred Langford Edwards

遠東地區第四紀真象科生物地層、古生態環境與演化之研究

Biostratigraphy, Palaeoecology and Evolution of Elephantidae in the Quaternary of the Far East

執行單位：國立自然科學博物館　地質學組

中 華 民 國 91 年 10 月 15 日

行政院國家科學委員會專題研究計畫成果報告

遠東地區第四紀真象科生物地層、古生態環境與演化之研究

Biostratigraphy, Palaeoecology and Evolution of Elephantidae in the Quaternary of the Far East

計畫編號：NSC 90－2116－M－178－002
執行期限：90 年 08 月 01 日至 91 年 07 月 31 日
主持人：程延年　　國立自然科學博物館 地質學組
計畫參與人員：張鈞翔　　國立自然科學博物館 地質學組

一、中文摘要

本研究計畫為三年之研究計畫，其目的在於針對第四紀遠東地區古菱齒象（包括中國大陸、日本與台灣），進行鑑識、比對與測量分析，建立該類群的演化與系統發育模式，探究其在第四紀的擴散、遷徙、滅絕事件與古生態環境之相關性。第二年的工作重點在於針對中國大陸、日本與台灣進行型態與記量分析。根據古菱齒象之臼齒型態、臼齒寬度、齒板頻率與琺瑯質摺皺程度，來自三個地區之古菱齒象存在顯著地地理性差異。推測，台灣地區與日本地區之古菱齒象同起源於中國華北地區，但為不同的遷徙路徑與演化趨勢。下一階段將針對該類群不同地區之分化特徵與古生態環境之相關性進行深入研究。

關鍵詞：真象科、第四紀、系統分類、演化

Abstract

The objective of this research project is to investigate and understand the biostratigraphy, palaeoecology and phylogenetic relationships of the Elephantidae from the Far East (including China, Japan and Taiwan) in the Quaternary. The task will be accomplished through the comprehensive analysis of morphological variation of fossils obtained from museums, research institutions and the field works, together with geographical and biostratigraphical information from the same sources.

Based on the study a large number of *Palaeoloxodon* on the morphology, width, lamellar frequency and enamel thickness of samples from China, Japan and Taiwan, the research indicates that *Palaeoloxodon* evolved in the Japanese Islands and Taiwan, respectively, and migrated to Japan and Taiwan from the mainland of China with the separated routes.

Further research will concentrate on the trends in tooth morphology to determine differences among geographical and chronological distributions with relation to climatic and vegetation changes.

Keywords: Elephantidae, Quaternary, Systematics, Evolution

二、緣由與目的

在古脊椎動物學的研究領域中，長鼻目（象類） 一直是一項熱門的研究重點，牠最早出現在始新世中晚期的非洲，中新世早期進入歐亞大陸，晚期進入美洲大陸，在更新世大肆繁衍發展，廣佈世界各地，種類之多，演化速度之快，堪稱是新生代地球上最占優勢的動物類群之一（Shoshani and Tassy, 1996）。然而到了更新世晚期大部分的象類都已滅絕，僅殘存亞洲象與非洲象。由於大象體型龐大，門齒型態特殊與複雜的頰齒發育模式與型態變異，一直吸引著古生物學家深入探究。牠的起源、發展、遷徙、分佈、變異為古生物學探究生物系統分類與演化之重要材料，也是探討古生態、古氣候變遷與生物地層年代之重要指標（Lister, 1989）。

台灣與日本同屬海島地形，位於亞洲大陸東緣北緯 45 度至 23 度，然而在第四紀冰河時期，曾因海平面下降而與大陸連接。從許多化石的證據顯示，在冰河時期曾經有多次哺乳動物的遷徙事件（Kawamura, 1998），包括來自西伯利亞的猛瑪象，中國華北動物群的古菱齒象與德氏水牛。台灣第四紀哺乳動物相與日本第四紀哺乳動物相可能有相同的起源（Takahashi and Namatsu, 2000），也可能隨著環境

不同的產生適應特徵的差異，也有可能兩者之間具有遷徙與親緣的關係。這些有趣的議題可望透過兩地間化石證據的分析研究加以釐清。

本研究針對蒐藏於國立自然科學博物館近千件各類象化石標本進行型態測量，再前往中國大陸和日本各地博物館與研究機構實地進行化石鑑識、比對與測量分析，期望重新檢視並詮釋演化系統親緣關係，追溯真象科在歐亞大陸的發展起源，與研究真象科在遠東地區各系譜之年代、地理分佈、分化特徵變異與環境變遷等議題。

三、結果與討論

象頭骨形態奇特，加上臼齒生長發育的連續排列推擠之特殊性，與齒版排列形態的歧異，增添許多鑑別分析的困難，所以真象科的分類系統與演化一直是爭議不斷(Froehlich and Kalb, 1995)。在古象頭骨化石完整保存不易的限制之下，臼齒化石成為重要的研究材料，針對臼齒發展出的研究方法，例如齒寬（width）、齒高指數（hypsodonty index）、齒板頻率（lamellar frequency）和琺朗質摺皺厚度（enamel thickness），也就成為研究古象化石的重要線索（Lister and Joysey, 1992）。

從本研究調查大陸、日本與台灣地區古菱齒象臼齒之琺朗質與齒寬之相對關係（圖一），台灣地區古菱齒象具有較大的體型與較厚的琺瑯質，相對於日本的古菱齒象則顯得個體較小。在齒板頻率方面（圖二），日本古菱齒象有較高的齒板頻率，台灣古菱齒象則較低。琺瑯質厚度與齒板頻率皆是環境適應與演化的具體呈現，與起源地的中國古菱齒象相比，台灣古菱齒象具有相似的琺朗質厚度與齒板頻率，亦即保留相當程度的原始特徵；而日本古菱齒象則朝向低琺瑯質厚度與高齒板頻率之較進步特徵發展。

綜合上述特徵與比較結果，台灣澎湖海溝古菱齒象與更新世晚期分佈在華北地區的諾氏古菱齒象（*Palaeoloxodon naumanni*）類似，而且體型更為龐大，齒版寬且長，齒版頻率底，具有相當程度的地方特色。

推測是在更新世晚期最後冰河時期，由華北地區動物群沿大陸東部沿海向南播遷而來，與日本地區古菱齒象為不同的獨立遷徙事件，亦即更新世晚期澎湖海溝動物群與日本動物群之間並沒有關連，而是各別起源來自華北地區動物群。至於是否因為棲息環境不同，產生食性的差異而產生臼齒結構變化？還是氣候因素改變植被狀況，還是與其它動物競爭而導致食性的改變，因而引起臼齒結構變化，本研究將藉由進一步分析各地區古菱齒象之族群結構，深入探討。

四、成果自我評量

傳統上古脊椎動物化石的研究經常受限於化石數量與交流不易，多數的研究在於個別標本的型態描述與分類鑑定。本研究透過國立自然科學博物館的大量館藏，逐一測量分析，以族群的觀點建立種系發育模式與特徵，以比較不同分佈地點族群間的特徵差異與演化趨勢。並將研究材料來源延伸至廣大遠東地區，已經超越了傳統式單一物種、單一地域的研究，而是跨區域、貫穿時間軸、整合性的研究。

未來更將以本研究成果為基礎，再進一步推動國際性合作研究，追溯真象科在歐亞大陸的發展起源，以及研究真象科在遠東地區各係譜之年代、地理分佈、分化特徵變異與環境變遷等議題。透過學術交流活動與推動國際博物館館際間的標本或複製品交換，逐步累積古象化石之研究成果與蒐藏品之質與量，並轉化成科學教育與展示之功能。

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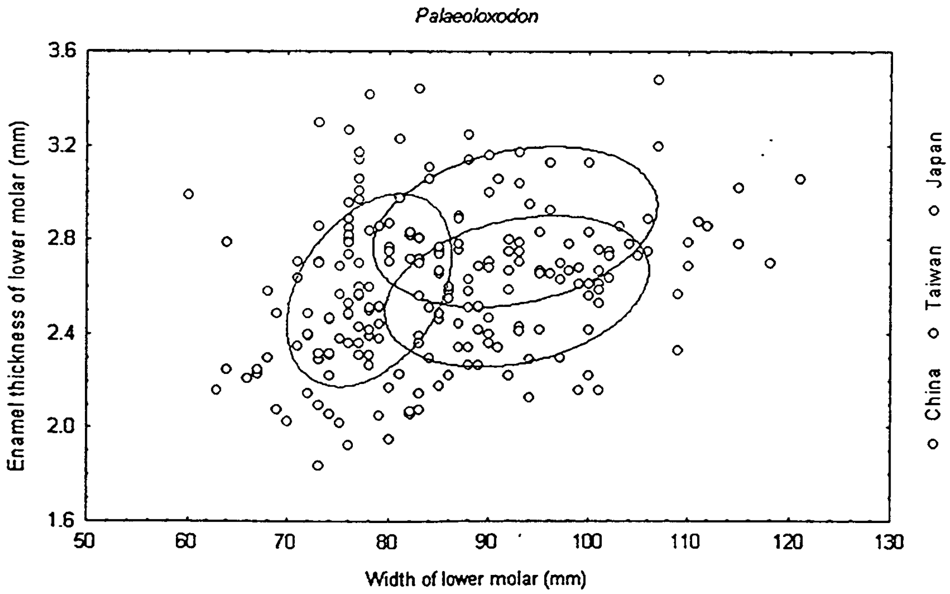
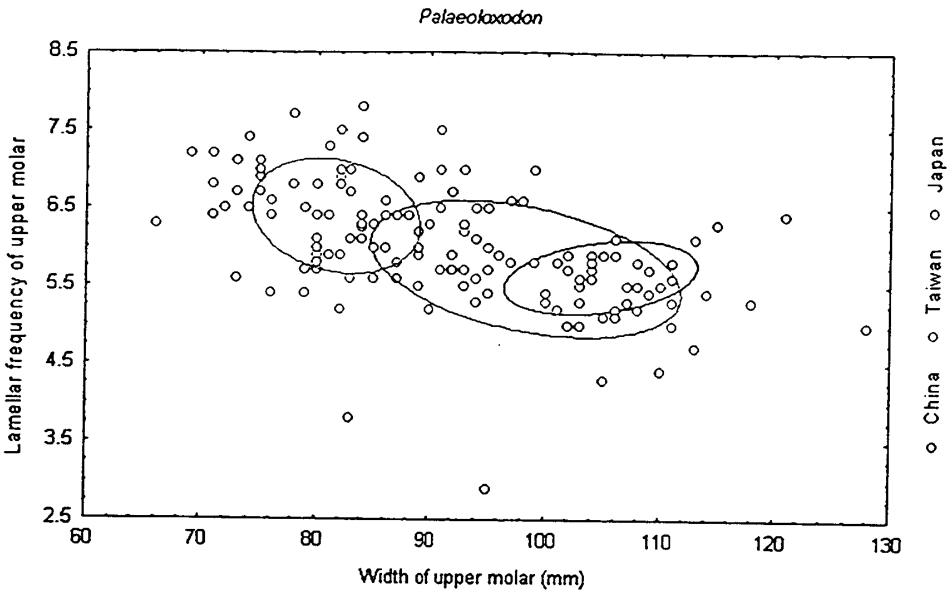


圖一：中国大陸、台湾與日本三地區古菱齒象之齒寬與琺瑯質厚度之相關性比較



圖二：中國大陸、台灣與日本三地區古菱齒象之齒寬與齒板頻率之相關性比較

and are excluded [see supplementary materials, Part 2 (an)]. For each study area, spatially replicate samples were pooled into habitat-level datasets on the basis of sedimentary grain size, seafloor features (bedforms, vegetation, mass properties), and salinity. These habitats are comparable in scale and distinctiveness to sedimentary facies in the stratigraphic record, and were defined independently of faunal data. Habitats are grouped into four broad environments: salt marsh and tidal creek; intertidal flats and channels; coastal embayment (lagoons, estuaries, rias, and other semi-enclosed coastal bays where water energy, salinity, and/or oxygen level are reduced); and shelf (includes shoreface sands above fairweather wavebase, and an array of shallow and deep-water muds, muddy sands, and actively-building and relict shell gravels).

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18. The 85 Spearman 2-values were not normally distributed by a chi-square test (d = 0.014), suggesting that they should be transformed using Fisher's (before weighting (by N-3) and averaging [L. V. Hedges, I. Olkin, turu)Pu)]e . xuycFP ic2 . xurchlresP)P (Academic Press, New York, 1985)]). However, all stratified subsets of the raw 2-values were normally distributed, and overall results of meta-analytically weighting and averaging (-transformed 2-values do not differ significantly from those using untransformed 2-values. The formal procedure of combining weighted results from many studies of disparate size and treatment (meta-analysis) has become a standard method in ecology, medicine, and the social and cognitive sciences where effect sizes are commonly small and diffuse, but is applied here to paleoecology for the first time.
19. Only 21% of ≤1 mm mesh comparisons show a significant correlation by a Sequential Bonferroni test [per W. R. Rice, -wcebu)d 43, 223 (1989)], whereas 84% of >1 mm coarse-mesh comparisons are significantly correlated after correction. If the threshold mesh is set at ≥2 mm, then 100% of datasets show a significant correlation, including after correction.
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26. Fine-mesh death assemblages have slightly lower representation of live species (87 ± 6% found dead; 38 data sets with >100 dead individuals), and lower agreement in species dominance (68 ± 6% of dead individuals are from species censused alive). An earlier synthesis using a methodologically variable set of live-dead studies also yielded lower estimates than the present analysis [S. M. Kidwell, in nzzfl Txœx Tr2b]y pcl ix2xl]x cl g{rl)Pv œxF)v xl u fl ux2r]ukcl P, J. Y. Aller, S. Woodin, R. C. Aller, Eds. (Univ. of South Carolina Press, Columbia, in press); see supplemental materials for list of studies used (an)].
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29. In general, strong rank-order agreement between a time-averaged death assemblage and a single-census of live fauna suggests that either (i) rank-order of the standing live fauna does not change significantly over the duration of time-averaged input, or (ii) community composition does change, but the death assemblage is numerically dominated by the most recent cohort(s) of dead input. The latter scenario is ecologically more likely, and is also consistent with strongly right-skewed frequency distributions of shell age-since-death [e.g., K. H. Meldahl, G. A. Goodfriend, K. W. Flessa, drexc:)cœ c[s 24, 287 (1998)]. This scenario implies that, although species richness values may well reflect input from the entire duration of time-averaging [e.g., conclusions of (n–ak n; k n/k n1–n4k //)], dominance information might reflect only a final short segment of total elapsed time and thus have higher time-resolution.
30. Additional bias does accrue with lithification and subaerial emergence of marine sedimentary records, even where aragonitic shells persist, but species preservation is still very high. For example, J. W. Valentine [drexc)ced{s 15, 83 (1989)] found that 77% of species living today in the Californian Province are preserved in Pleistocene terrace deposits.
31. Supplementary materials are available at www.sciencemag.org/cgi/content/full/294/5544/1091/DC1.
32. I thank original authors for discussion and permission to reanalyze their raw data, L.V. Hedges and C. W. Osenberg for meta-analytic statistical advice via the U.S. National Center for Ecological Analysis and Synthesis, M. Foote and D. Jablonski for early reviews, and the many individuals who assisted my search for datasets, especially associates of the U.S. National Museum of Natural History (Smithsonian Institution), Natural History Museum (London), Texas Bureau of Economic Geology, and California Academy of Sciences.

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The Origin and Evolution of the Woolly Mammoth

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The mammoth lineage provides an example of rapid adaptive evolution in response to the changing environments of the Pleistocene. Using well-dated samples from across the mammoth's Eurasian range, we document geographical and chronological variation in adaptive morphology. This work illustrates an incremental (if mosaic) evolutionary sequence but also reveals a complex interplay of local morphological innovation, migration, and extirpation in the origin and evolution of a mammalian species. In particular, northeastern Siberia is identified as an area of successive allopatric innovations that apparently spread to Europe, where they contributed to a complex pattern of stasis, replacement, and transformation.

Testing among models of species-level evolution in the fossil record ideally requires abundant samples that are finely stratified, accurately dated, and correlated across a broad geographical area (*1*). Most previous studies of fossil mammals have lacked the resolution to identify lineage splitting in contrast to phyletic change, nor have they offered sufficient geographical spread to distinguish in situ transformation from immigration (*2*, *3*). Among large mammals, the mammoth lineage has one of the most complete records as well as pronounced adaptive morphological evolution through a time of well-studied environmental change. It also allows us to address the issue of geographical variation by sampling correlated sequences in both the European and Siberian parts of the mammoth's Eurasian range.

European mammoths (*Mammuthus*) have conventionally been divided into three chronospecies: the Early Pleistocene *M. meridionalis* [recorded about 2.6 to 0.7 million years ago (Ma)], the early Middle Pleistocene *M. trogontherii* (~0.7 to 0.5 Ma), and the woolly mammoth *M. primigenius* of the late Middle and Late Pleistocene (~0.35 to 0.01 Ma). Important changes through this sequence include shortening and heightening of the cranium and mandible, increase in the height of the molar crown (hypsodonty), increase in the number of enamel bands (plates) in the molars, and thinning of the enamel (*4*–*6*) (Fig. 1). The dental changes resulted in increased resistance to abrasion, which is believed to correlate with a shift from woodland browsing to grazing in the open grassy habitats of the Pleistocene.

Critical to our study is the selection of samples that are chronologically restricted and independently dated (*7*). Dating methods for source deposits include radiometry (e.g., K/Ar or ^{14}C), electron spin resonance/thermoluminescence, paleomagnetism, amino acid epimerization, first- and last-appearance datum of marine microfossils, and associated mammalian fauna. Samples from ~500,000 years ago (500 ka) onward can be tentatively correlated with marine isotope stages (MIS) (*8*).

The variable most frequently used in tracing elephantid evolution is lamellar frequency of

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the molar teeth (LF), defined as the number of enamel plates in a 10-cm length of crown (*4*). Fourteen European samples are plotted in Fig. 2, spanning ~2.6 Ma to 25 ka, and show a largely directional trend: Rank correlation against time is highly significant ($P < 0.001$) (*9*). This is of adaptive significance, as lamellar spacing is critical to elephant dental function (*4*). However, the apparently gradualistic sequence is somewhat misleading, because LF can be raised not only by an evolutionary increase in the number of plates in the crown, but also by a simple reduction in size: Isometrically smaller teeth with identical plate counts have more closely spaced plates (*10*). Because mammoth size varied through the Pleistocene (*6, 10*), this could be responsible in part for the LF trend.

We have therefore plotted the raw number of plates (P) in complete third molars (Fig. 3A) (*11*). A second, independent variable, the hypsodonty index (HI), is plotted for third upper molars in Fig. 3B (*12*); this character is linked to important concomitant changes in skull architecture (deepening of cranium and mandible). The earliest known mammoths, *M. subplanifrons* from southern and eastern Africa (~4 Ma), with very low plate number (P = 7 to 9 only) and shallow crown (HI = ~0.6 to 0.9), are the most primitive sample.

The oldest European population is based on a combined sample from Britain (Red Crag), Italy (Montopoli), and Romania (Cernatesti), all around 2.6 Ma. Hypsodonty is already at typical *M. meridionalis* level, but plate number shows a transitional condition from the African progenitor, with only 9 to 11 plates in third molars.

Typical *M. meridionalis* morphology (P = 12 to 14, with outliers at 11 and 15, and mean HI = ~1.2) is achieved by ~2.4 to 2.2 Ma (Khapry), and P remains in stasis for around a million years, through ~1.8 Ma (Upper Valdarno, the type area of the species) to Pietrafitta (~1.4 Ma).

Around 1.0 Ma, some samples show little change (*13*) or slight advancement in P to a range of 13 to 15 [e.g., St-Prest, France (Fig. 3)]. However, an east European sample from the Taman' Peninsula, Azov Sea, codified as the "advanced form" *M. meridionalis tamanensis* (*14*), shows enhanced variability in the direction of *M. trogontherii* and has been posited as a key "intermediate" between the two species. But although this sample as a whole is intermediate in both P and HI between the type *M. meridionalis* and *M. trogontherii*, it has a rather broad morphological range (P = 14 to 19, HI = 1.3 to 1.8), and the distribution of these characters is bimodal (Fig. 3) (*15*), unexpected for a simple anagenetic intermediate.

At around 700 ka, two smaller samples, from Voigtstedt, Germany [*M. meridionalis voigtstedtensis* (*16*)], and West Runton, England (type Cromerian plus adjacent late Beestonian gravels), are of very similar age (*17*). They include molars at full *M. trogontherii* level (P = 19 to 22, HI = 1.6 to 1.9), but also specimens showing persistent "advanced *M. meridionalis*" morphology in one or more characters (Fig. 3) (*18*). P and HI are only partly congruent at Taman' and Voigtstedt: Some specimens are of "mosaic" morphology (low P, high HI), whereas a few others show "intermediate" values (P = 16, HI = 1.5) between typical *M. meridionalis* and *M. trogontherii* (Fig. 3).

By ~600 ka, only *M. trogontherii* occurred in Europe, as at Süssenborn, the type locality of the species. The sample from Mosbach (~500 ka, probably MIS 13) is equivalent to Süssenborn in plate number, but shows an increase in mean HI to ~2.0, bringing it to the maximum level of the lineage, a further example of mosaic change.

Mammoth samples postdating the Anglian/Elsterian glaciation in Europe (~450 ka, probably MIS 12) have often been regarded as early forms of woolly mammoth *M. primigenius* on the basis of increased LF relative to *M. trogontherii* (*19, 20*). However, the change in this variable is misleading and masks underlying stasis. The rising LF trend (Fig. 2) from Mosbach (~500 ka) through Steinheim (~350 ka) to Ilford (~200 ka) is due entirely to compression of the molar plates resulting from the size reduction experienced by mammoths through this part of the sequence (*6, 10*). Plate number itself, the true indicator of evolutionary level, remained in stasis at the "*M. trogontherii*" level through the interval 600 to 200 ka (Fig. 3A). Other dated European samples that we have measured—such as Ariendorf, Germany (~300 to 150 ka), Tourville la Rivière, France (~230 ka), and several MIS 7 sites such as Stanton Harcourt, England, and Ehringsdorf, Germany (~200 ka)—corroborate the late persistence of *M. trogontherii* morphology (*21*).

Moreover, there is evidence that the end of this interval is marked by the simultaneous occurrence in Europe of mammoths of *M. trogontherii* and *M. primigenius* morphology. The sample from Marsworth, UK, of late MIS 7 or early MIS 6 age (~190 to 150 ka) was carefully collected from a single horizon. It shows a wide spread of P values with an apparently bimodal distribution, the two modes closely corresponding in morphology to the immediately preceding (*M. trogontherii*) and succeeding (*M. primigenius*) populations. A similar distribution of P values (18 to 24) is seen in a smaller sample from another site, Brundon (Suffolk, UK), of late MIS 7 age (*22*).

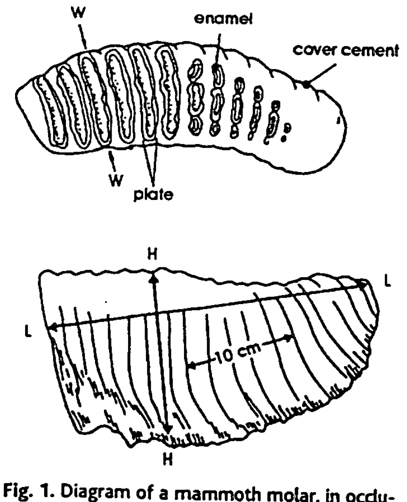

Fig. 1. Diagram of a mammoth molar, in occlusal and lateral views, showing measurements taken. W-W, width; L-L, length; H-H, height (1k nnk n/).

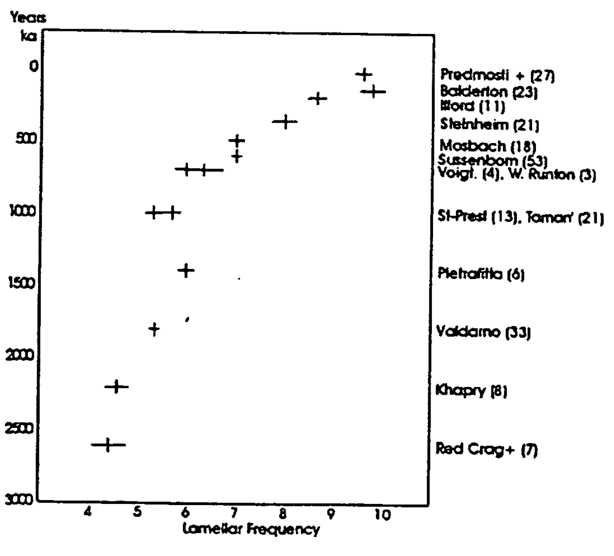

Fig. 2. Lamellar frequency of third upper molars in European mammoths, plotted against linear time. Mean ± 1 standard error shown. For West Runton, only "uᶑc[c l uyx2)" specimens, omitting the "v x2F)cl re)P" molar at P = 15 (see Fig. 3A), are included. Sample sizes are in brackets.

In keeping with this timing for the transition, several samples from MIS 6 (~190 to 130 ka) represent the earliest sole occurrence of *M. primigenius*, fully derived in all characters, in Europe (*23*). These include La Cotte, Jersey, Channel Islands (UK); Tattershall Thorpe, Lincolnshire, England; Zemst IIb, Flemish Valley, Belgium; and Balderton, Nottinghamshire, England, the latter plotted in Figs. 2 and 3. Similar mean values for all variables persist in almost all European samples from the "last cold stage" (MIS 4-2) (Figs. 2 and 3). Many of these latest samples do, however, show a marked degree of intrapopulation morphological spread (Fig. 3), including specimens reminiscent of *M. trogontherii* in P values (*24*).

Our Siberian sequence shows morphological transitions similar to those in Europe, but persistently ahead of Europe in the timing of successive morphologies. Our samples are all from northeastern Siberia, between the Lena and Kolyma River valleys; the earliest, from the Early Olyorian, spans 1.2 to 0.8 Ma. From this date or earlier, mammoths in northeastern Siberia were living in an herb- and grass-dominated environment under permafrost conditions (*25*). The Early Olyorian sample is approximately equivalent to the European Taman' sample in age but is more derived in plate count, whereas in hypsodonty it corresponds only to the "advanced" mode at Taman' (Fig. 3). Except in a smaller size of teeth, the Early Olyorian sample is barely distinguishable from *M. trogontherii*, which does not appear in Europe until ~700 ka.

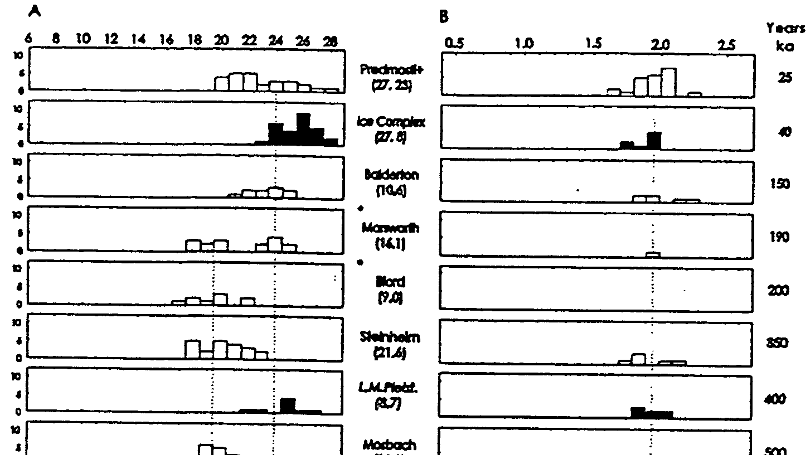

Fig. 3. (A) Plate count (P) of third upper plus lower molars; (B) hypsodonty index (HI) of third upper molars in the mammoth lineage. Open bars: European samples (shaded, Voigtstedt); filled bars and italic names/ages: northeastern Siberian samples; cross-hatched bars, African sample. Solid vertical lines connect sample names of equivalent age. Dotted lines traverse groups of samples (or subsamples, in the case of Taman' HI and West Runton and Marsworth P) at similar evolutionary level. Asterisks indicate conventional significance levels (two-tailed utests; *d = 0.05, **d = 0.01, ***d = 0.001) between successive, whole European samples only (i.e., bimodal samples are treated as a whole, and Siberian samples are ignored); P to the left of the central gutter, HI to the right. HI of .m Pb:Cr l)i2cl P is shown as mean ± 1 standard error and 1 standard deviation, from (1). Sample sizes (P, HI) in brackets are after site names.

By the Late Olyorian (~800 to 600 ka), mammoths in Siberia approached *M. primigenius* morphology in all characters, anticipating the European sequence by several hundred thousand years; by the Late Pleistocene (~150 to 10 ka), Siberian mammoths exceeded European values in mean plate number (although not in hypsodonty) (Fig. 3), with "relict" *M. trogontherii* morphology much rarer than in Europe.

In sum, the pattern of change in Europe, although incremental on a broad time scale, includes substantial intervals of stasis and—at the two intervals of important transition—bimodality, which suggests more complex populational or cladogenetic processes. In keeping with this pattern, the early development in northeastern Siberia of advanced mammoths similar to later European *M. trogontherii* suggests the origin of this morphology in northeastern Siberia (presumably from an eastern *M. meridionalis* population), followed by its later dispersal to the south and west, where it eventually superseded the indigenous *M. meridionalis* morphology. Previous authors have questioned the simple descent of *M. trogontherii* from *M. meridionalis* in Europe (*26*) or have suggested the occurrence of two forms of mammoth there in the interval ~1.0 to 0.8 Ma (*13*), but the source of the more advanced form was not known. It may be significant that the earliest detected *M. trogontherii* morphology in Europe is at the eastern fringes of the continent (Taman'), whereas penecontemporaneous samples in western Europe (e.g., St-Prest) remained at a primitive *M. meridionalis* level.

However, the complexity of variation in Europe between 1.0 and 0.5 Ma, with incremental morphological advancement and mosaic or intermediate specimens within the samples, suggests that Early Olyorian immigrants were not completely reproductively isolated from the contemporary European population, but received some genetic input from it through this period (*27*). This is consistent with the fact that *M. trogontherii* at West Runton and even Süssenborn are still slightly more "primitive" than the ancestral

Early Olyorian population in features such as mean plate number (Fig. 3A) and enamel thickness (*28*).

In the second part of the sequence, comprising the shift from *M. trogontherii* to *M. primigenius* (~500 to 200 ka), our reappraisal of the European sequence suggests that a transition formerly assumed to be "gradualistic" in fact entails stasis followed by apparent sympatry and then replacement, a conclusion strengthened by the absence of a transitional population in Europe. Previous suggestions of differently adapted mammoth populations in Europe from 200 to 100 ka (*29, 30*) have been based on remains from a variety of deposits, and so could not distinguish between cladogenesis (implied by sympatry) and rapid anagenesis between populations of slightly differing ages. Moreover, the fossil sequence in northeastern Siberia demonstrates, as early as the Late Olyorian (~800 to 600 ka) and certainly by the late Middle Pleistocene (~500 to 200 ka), mammoths essentially indistinguishable from later European *M. primigenius*. This invites the hypothesis that the transition between the two chronospecies occurred in Siberia, with *M. primigenius* morphology later spreading to Europe.

In this transition as in the earlier one, a modified hypothesis to strict allopatric replacement would be partial introgression from the European to the incoming Siberian population (*27*). The persistence of some *trogontherii*-like variation within Late Pleistocene European *M. primigenius* is likely to be the heritage of an incomplete genetic barrier between the two species in the Middle Pleistocene, which, in view of the apparent isolation of the two forms at Marsworth, implies complex and variable degrees of isolation within a metapopulation around the time of speciation. In accordance with our model, the rarity of relict *M. trogontherii* morphology in Late Pleistocene Siberia reflects its phyletic transformation into *M. primigenius* there, in contrast to Europe, where both forms may have contributed to later populations.

This study shows that substantial evolutionary transformation can be effected through a sequence of intermediate morphologies over several hundred thousand to a few million years—in this sense "gradual," or better, incremental (*31*). It is also clear that different characters change at different times: "mosaic" evolution or, in phylogenetic terms, the order of building of the character complex. In Europe, P increases in several significant steps spread across the interval 2.6 to 0.15 Ma, whereas HI undergoes its major change in two bursts between 1.0 and 0.5 Ma (Fig. 3).

The incremental, directional change observed both in Europe and in Siberia might be accounted for by separate anagenesis, convergent between the two regions. However, from a cladistic perspective, it is more parsimonious to regard the shared dental and cranial features of Olyorian and European mammoths as evidence of phylogenetic links in the origin both of *M. trogontherii* and of *M. primigenius*, and this is supported by the patterning among samples in time and space. The earlier origin of *M. trogontherii* and *M. primigenius* morphologies in Siberia, and the enhanced variation or bimodality in Europe around the times of transition, are consistent with a critical input from outside, whether by simple replacement or (more likely) by more complex metapopulation processes including hybridization. The pattern of stasis and change in Europe shares elements with a "punctuated equilibrium" pattern of evolution (*1–3*). However, species origins in this example are not as clear-cut as in classic allopatric models, but apparently proceeded through the differential development of partially isolated populations.

Finally, our data should allow testing of correlations between the pattern of evolutionary change and the shifting paleoenvironments of the Pleistocene. For the moment, we note that the early initiation and persistent advancement of grazing adaptations in Siberian mammoths, compared to those in Europe, was very likely linked to the earlier advent and greater severity and continuity of periglacial conditions in that region (*32*). Siberia thereby provided a continuing source of grazing-adapted mammoths, which we suggest acted as a repeated source of evolutionary advancement into periodically glaciated Europe.

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7. For details of localities, with dating methods and references, see t])x(]x Online (www.sciencemag.org/cgi/content/full/294/5544/1094/DC1).
8. Errors attach to absolute date estimates, but the relative ordering of the samples is not in doubt. All European samples are single-site assemblages, except for "Red Crag +" and "Předmostí +," each of which is pooled from two or three sites of equivalent age and morphology. Each of the four Siberian samples is pooled from different collecting stations of the same geological unit (A).
9. We have not performed tests against random walk models (aa) because available models do not accommodate complex multipopulation processes, and because, in the face of major morphological change in a clearly adaptive character complex, we would not regard a nonsignificant result as sufficient evidence against "deterministic" evolution.
10. A. M. Lister, K. A. Joysey, in tu2t]ub2xk9b(]u)d r lF -wcebu]d d Uoxuyk P. Smith, E. Tchernov, Eds. (Freund, Tel Aviv, 1992), pp. 185–213.
11. Plate count (P) was measured on upper and lower third molars, and the data were pooled. P excludes talons, the small plate-like structures found at the anterior and posterior ends of each molar (1).
12. The hypsodonty index (HI) is calculated as the ratio between the maximum height (H, Fig. 1) and maximum width (W) of the crown (including cement), and is thus normalized for molar size. In partially worn or damaged teeth, HI was calculated only if plates in the "standard zone" of maximal crown height are preserved unworn (a1).
13. Small samples from Untermassfeld, Germany, and Oriolo, Italy (a7), both from ~1 Ma, are of typical . m v x2)F)dre)P molar morphology.
14. I. A. Dubrovo, dr erSym3, 82 (1964).
15. The geological setting of the Taman' sample suggests rapid deposition, with no evidence of time-stratigraphic mixing (a4). This indicates that the broad range and apparent bimodality of the sample are not explicable as the capture of two points in a rapidly evolving population, a conclusion supported by the existence of mosaic specimens.
16. W. O. Dietrich, dr erdumh: ymA II, 521 (1965).
17. A. J. Stuart, A. M. Lister, 5 brumt])m x wn20, 1677 (2001).
18. The observations based on third molars (Fig. 3) are supported by the larger sample of all molar generations. See explanations in text.
19. Steinheim: W. O. Dietrich, Hy2xPym Dx2mDrux2m I rub2MrN82mxv: m68, 42 (1912).
20. Ilford: K. S. Sandford, 5 mHr6x cemtc]m 81, 62 (1925).
21. The persistence of . mu2c[duyx 2))(as . mu2c[duyx 2))]ycPr 2)]bR into the late Middle Pleistocene was suggested in (aA) on the basis of isolated specimens from miscellaneous deposits in European Russia.
22. A. M. Lister, data not shown.
23. The earliest appearance of . mC2)v)[xl)bP in Europe was formerly placed at ~450 ka on the basis of a sample from Homersfield, Norfolk (4). This material has, however, been reallocated to a younger deposit of uncertain age (afl).
24. The two localities forming the latest European sample in Fig. 3 (Předmostí, Czech Republic, and Lea Valley Gravels, England), both show wide spread, with P ranges of 20 to 27 and 20 to 28, respectively.
25. A. V. Sher, in Lk22Pu2)edr excxlw)2dvx lure tubF)xP] Tx2)l( )r kM. E. Edwards, A. V. Sher, R. D. Guthrie, Eds. (Univ. of Alaska Museum, Fairbanks, AK, 1997), pp. 3–6.
26. A. Azzaroli, huu)h]]r Fml r(m()l]x) . xv . pem] m9)(. rum ru. tx2mfl 14 (sez. A), 149 (1977).
27. C. D. Jiggins, J. Mallet, U2xlFP -]cem-wcem15, 250 (2000) illustrate various patterns of morphological variation in hybrid populations, including bimodal distributions.
28. A. V. Sher, A. M. Lister, in preparation.
29. Some authors [e.g., (az)] have suggested an ecological separation between more woodland- and grazing-adapted mammoth populations in Europe at various times in the Pleistocene.
30. See also I. V. Foronova, A. N. Zudin, Rx)lPxr 6, 103 (1999).
31. A. M. Lister, 5 brumfilum19, 77 (1993).
32. A. V. Sher, dr erxcl ud 2nfiuenT4, 97 (1986).
33. P. D. Roopnarine xu r e, dr exc)ced s 25, 41 (1999).
34. A. V. Sher, V. E. Garutt, RcMehMrFmlr bMttt, 285, 221 (1985).
35. M. P. Ferretti, -] ec[m6x cem3 xew82, 503 (1999).
36. A. V. Sher, in tx] dF filux2lru)dre . rvv cuy pdi x2o xl] xB gi J])r epdi x2xl]x drCx2l J. W. F. Reumer, J. de Vos, Eds. (Natuurmuseum, Rotterdam, 1999), pp. 56–58.
37. I. A. Dubrovo, Tsbeer(cvm fi(b)ympyx uwrdx2n82, 63 (1966).
38. D. Schreve, in 9cPf)e . rv vr eP rlF T)2fP cl 62xru T2]ur)l M. Benton, E. Cook, D. Schreve, A. Currant, J. Hooker, Eds. (Joint Nature Conservation Committee, Peterborough, UK, in press).
39. T. Kotsakis, M. R. Palombo, C. Petronio, 6x cemcv m 17, 411 (1978).

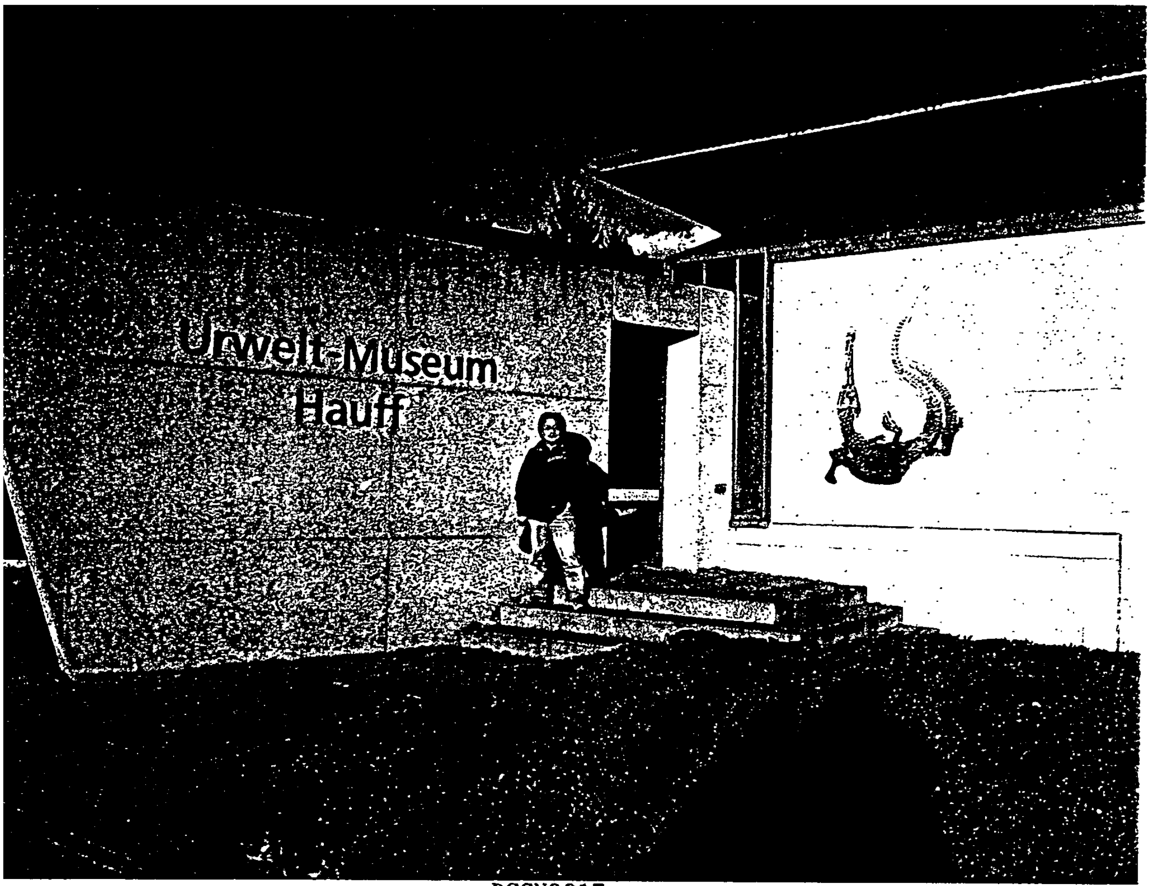
40. We thank the UK Biotechnology and Biological Sciences Research Council, the Russian Foundation for Basic Research, and the Royal Society for support; P. Bown, M. Ferretti, V. E. Garutt, D. Jablonski, R.-D. Kahlke, D. Schreve, and R. Ziegler for discussions; V. E. Garutt, M. Ferretti, and J. A. van Essen for help with data collection; and the curators of various museums for access to material.

5 October 2000; accepted 12 September 2001

MAMMOTHS

ADRIAN LISTER AND PAUL BAHN

Foreword by Jean M. Auel



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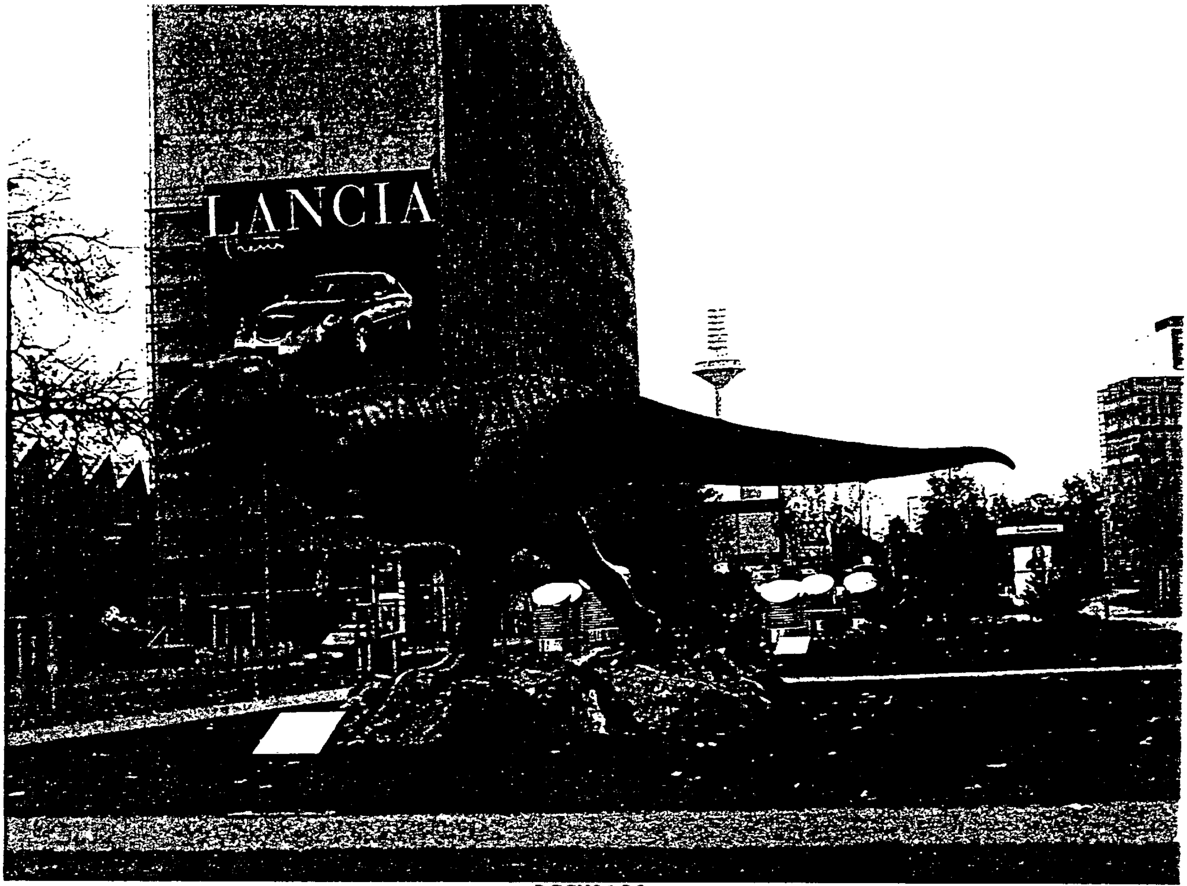

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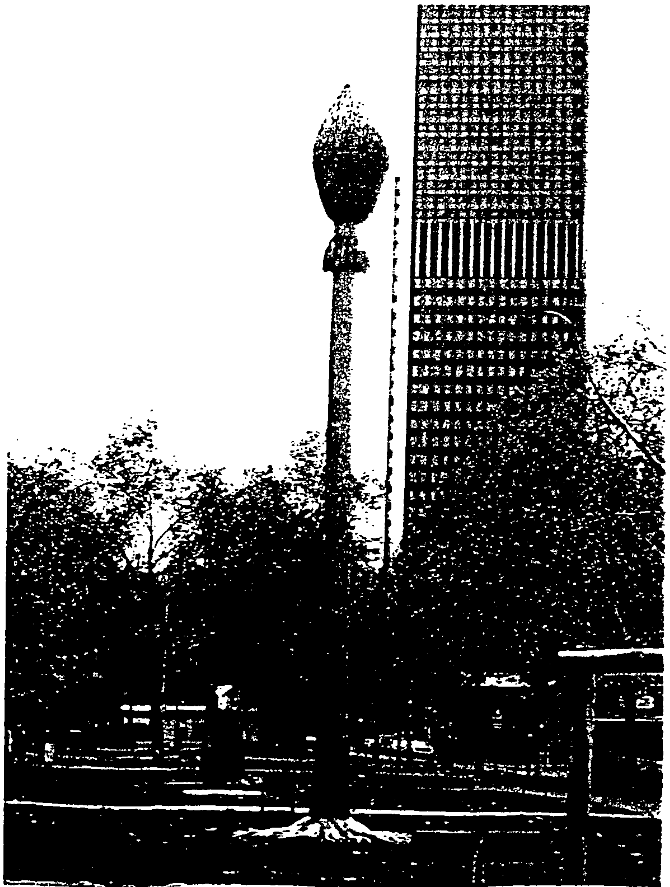
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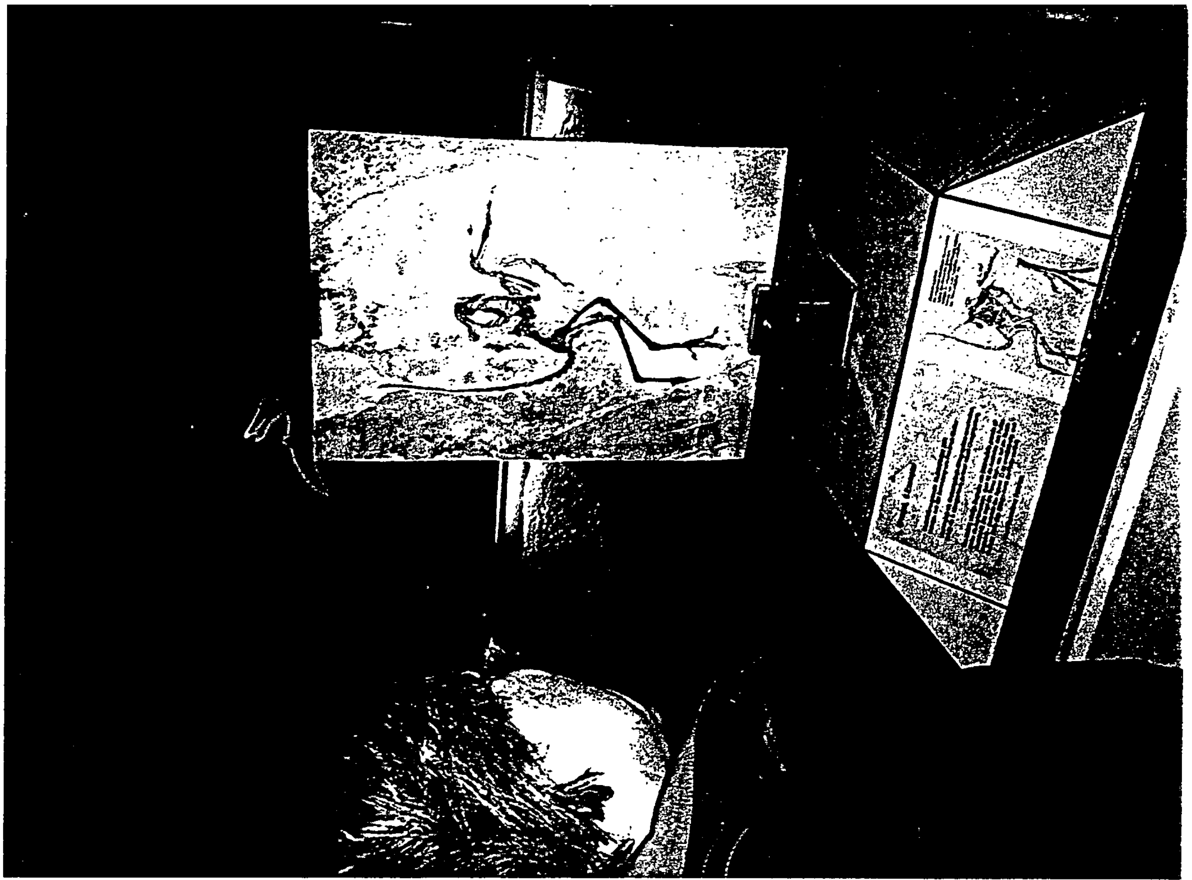

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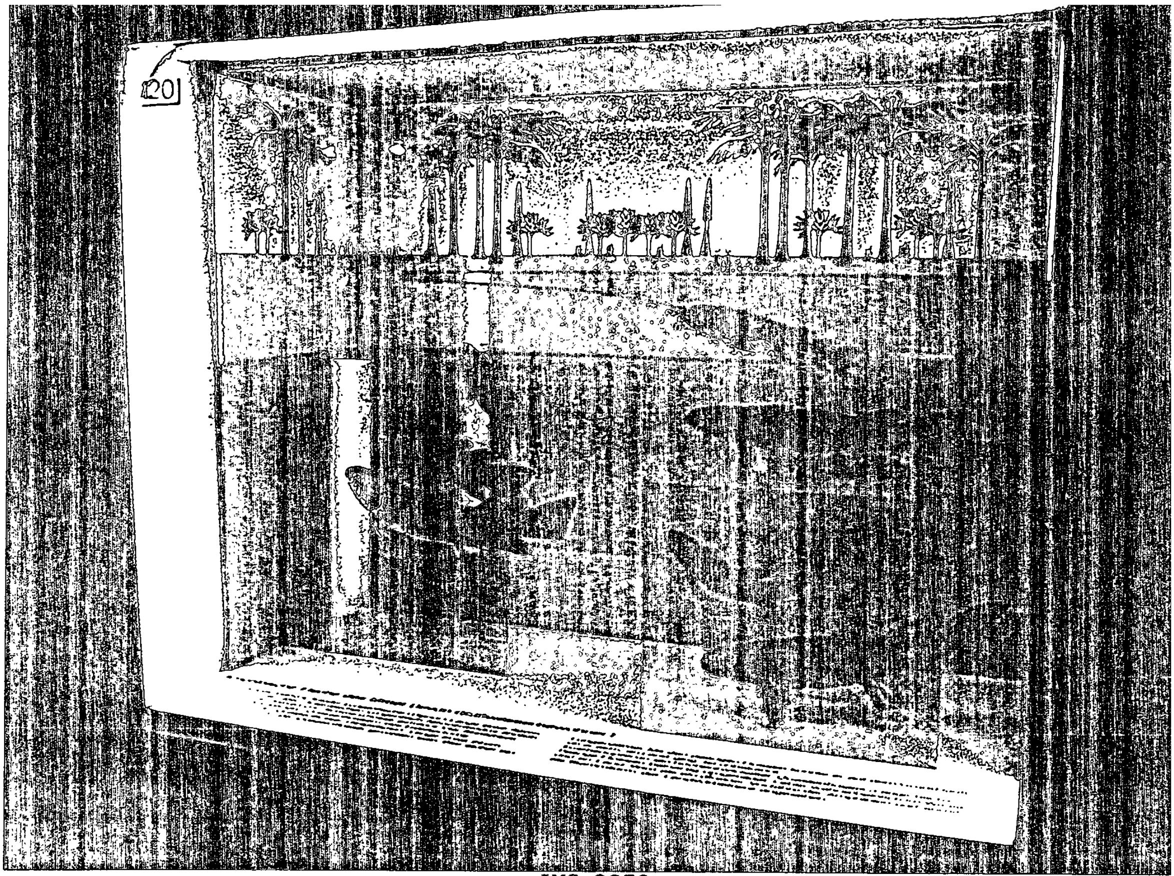
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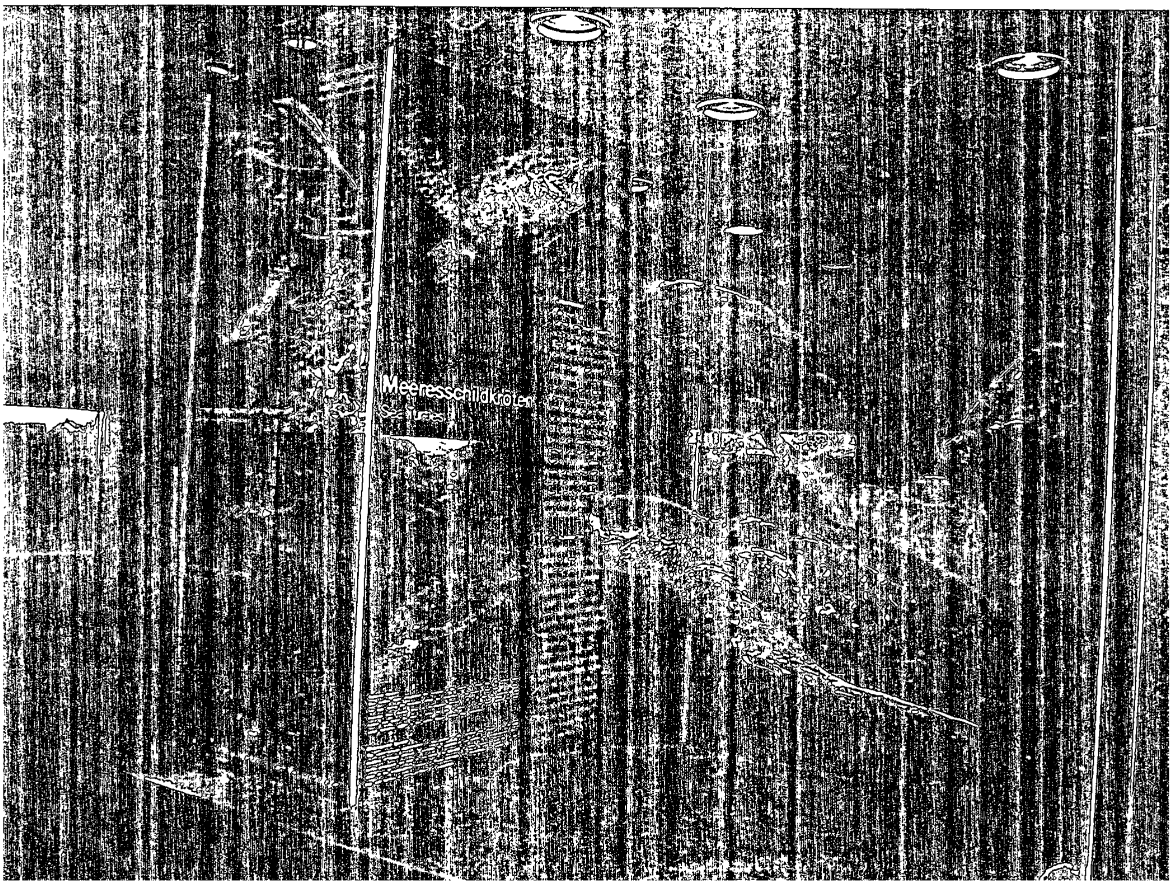

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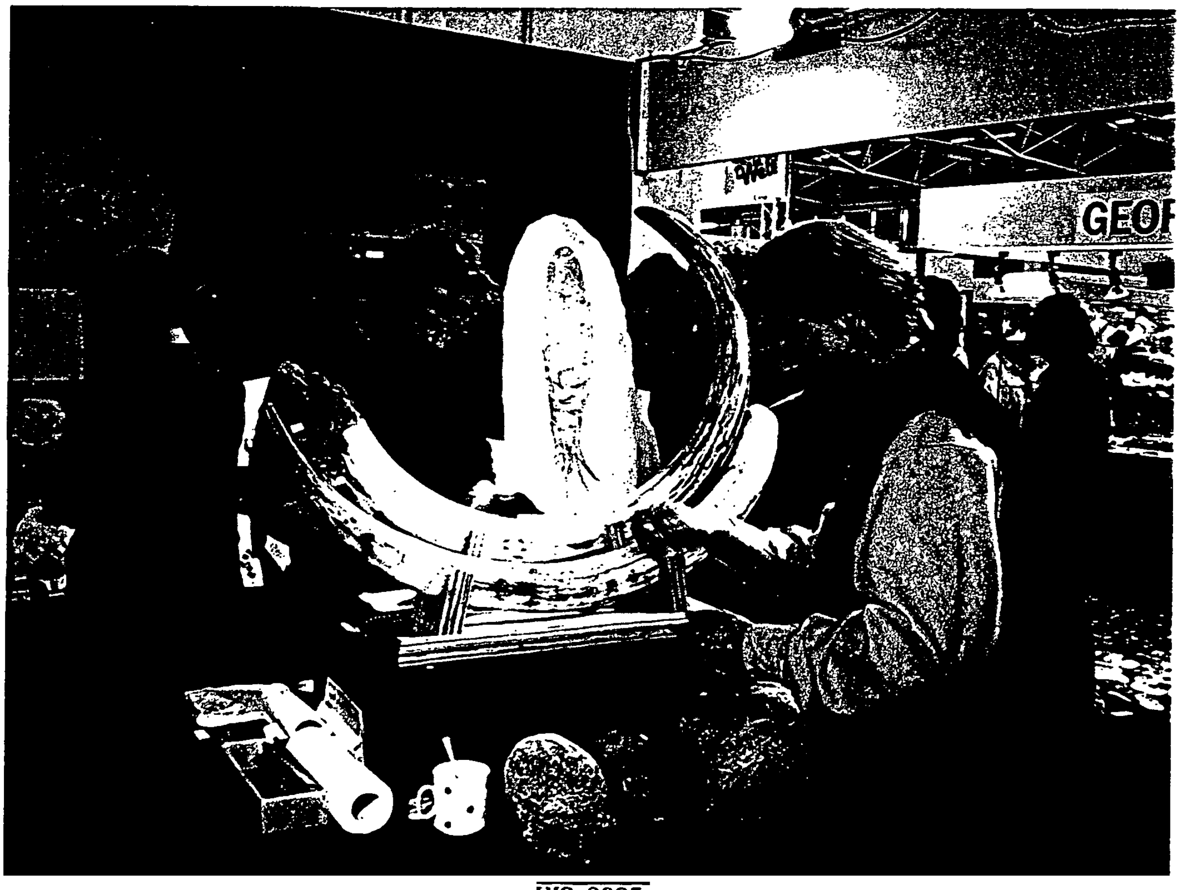

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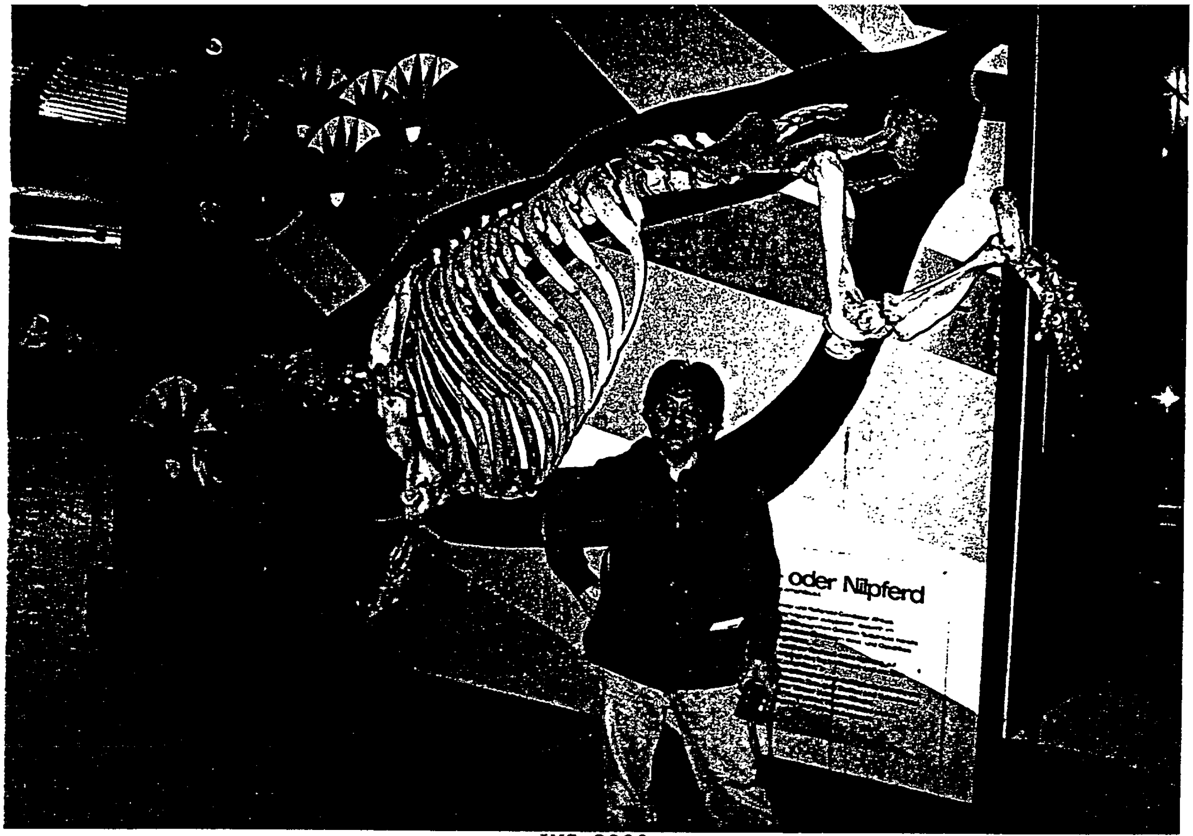

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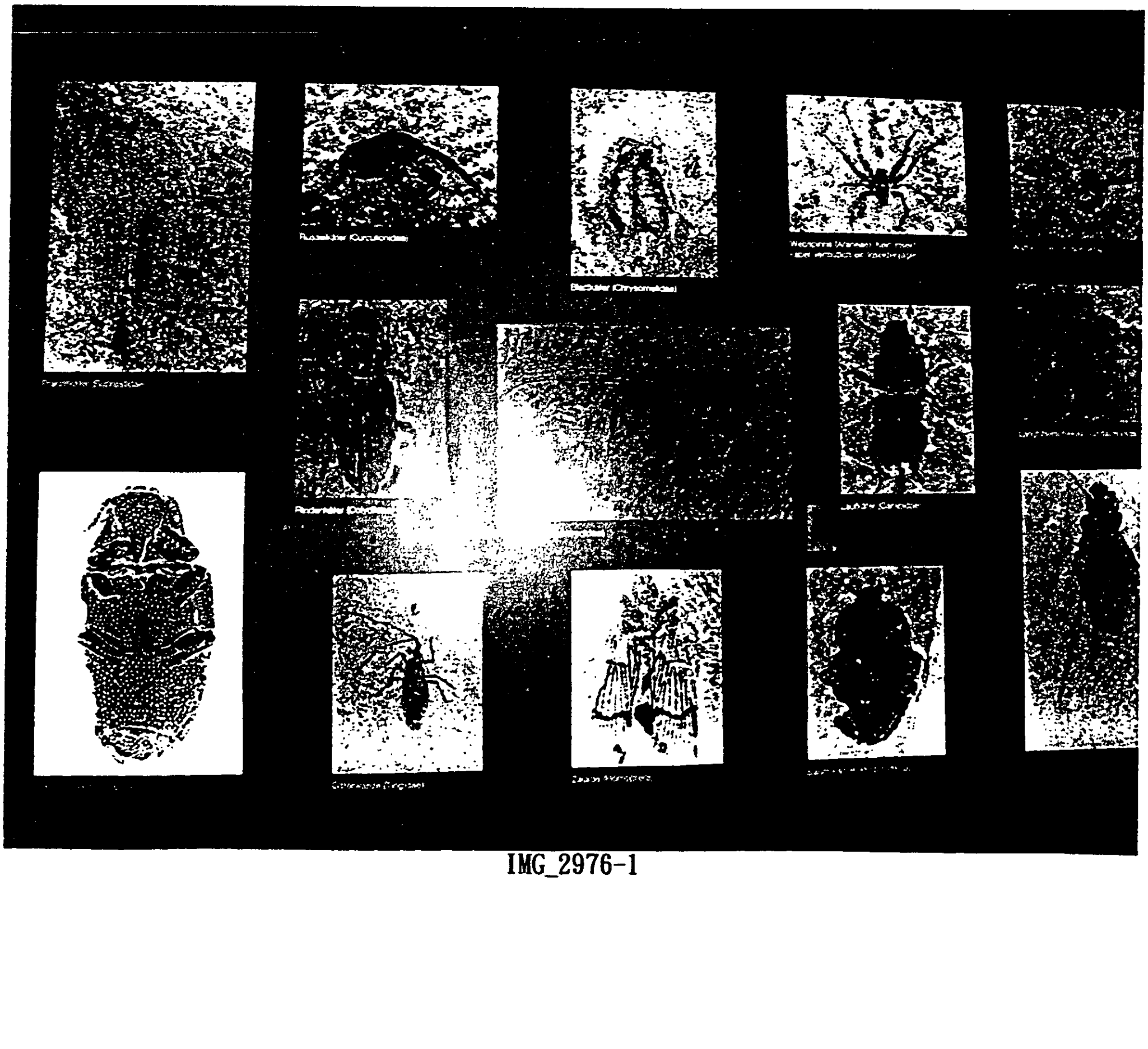
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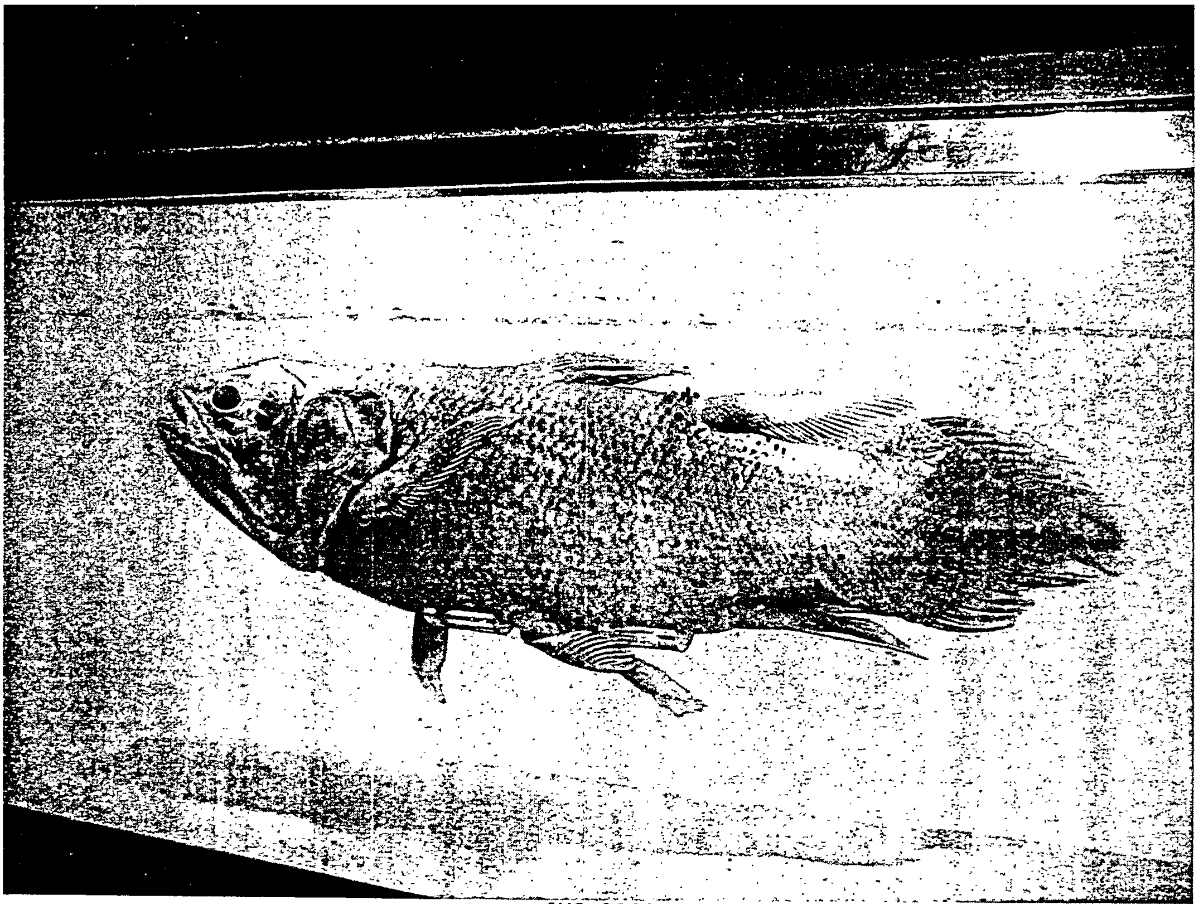

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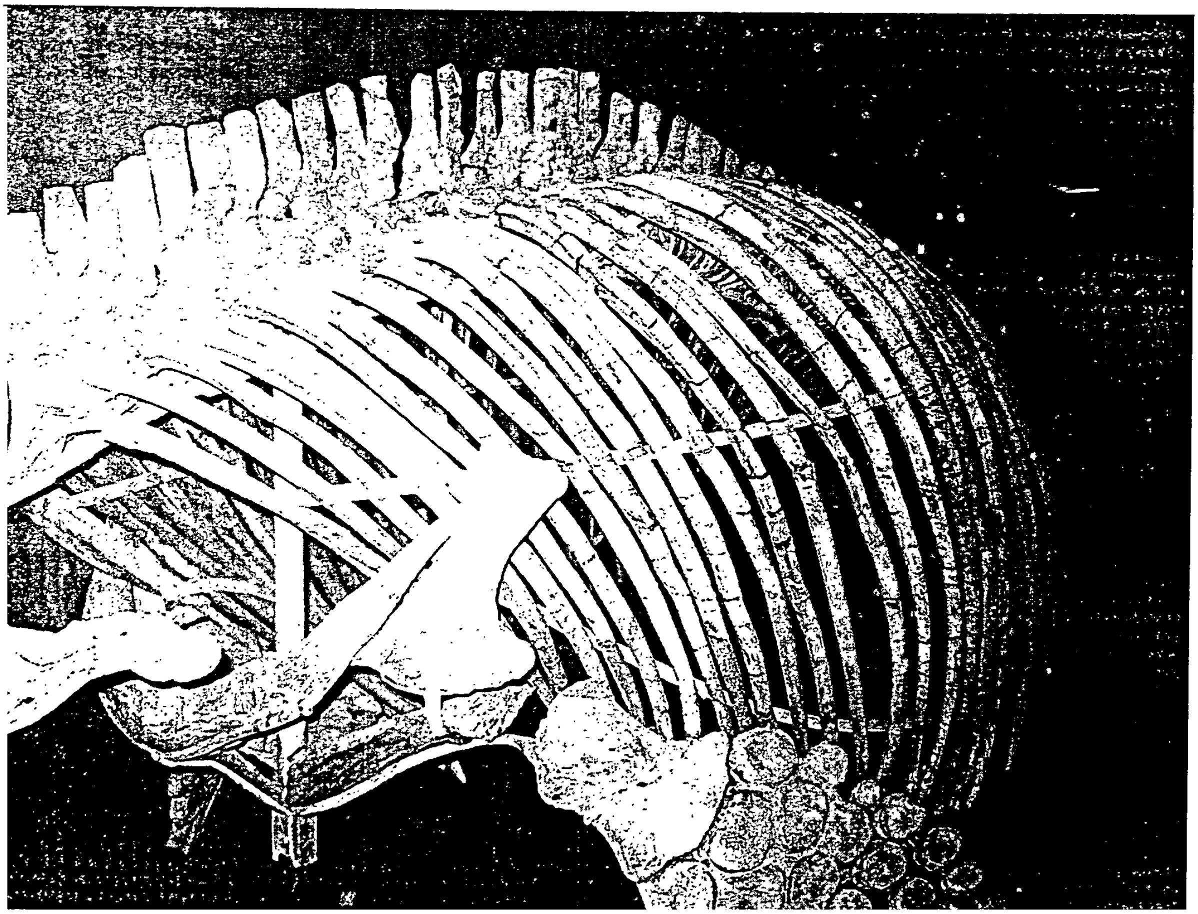

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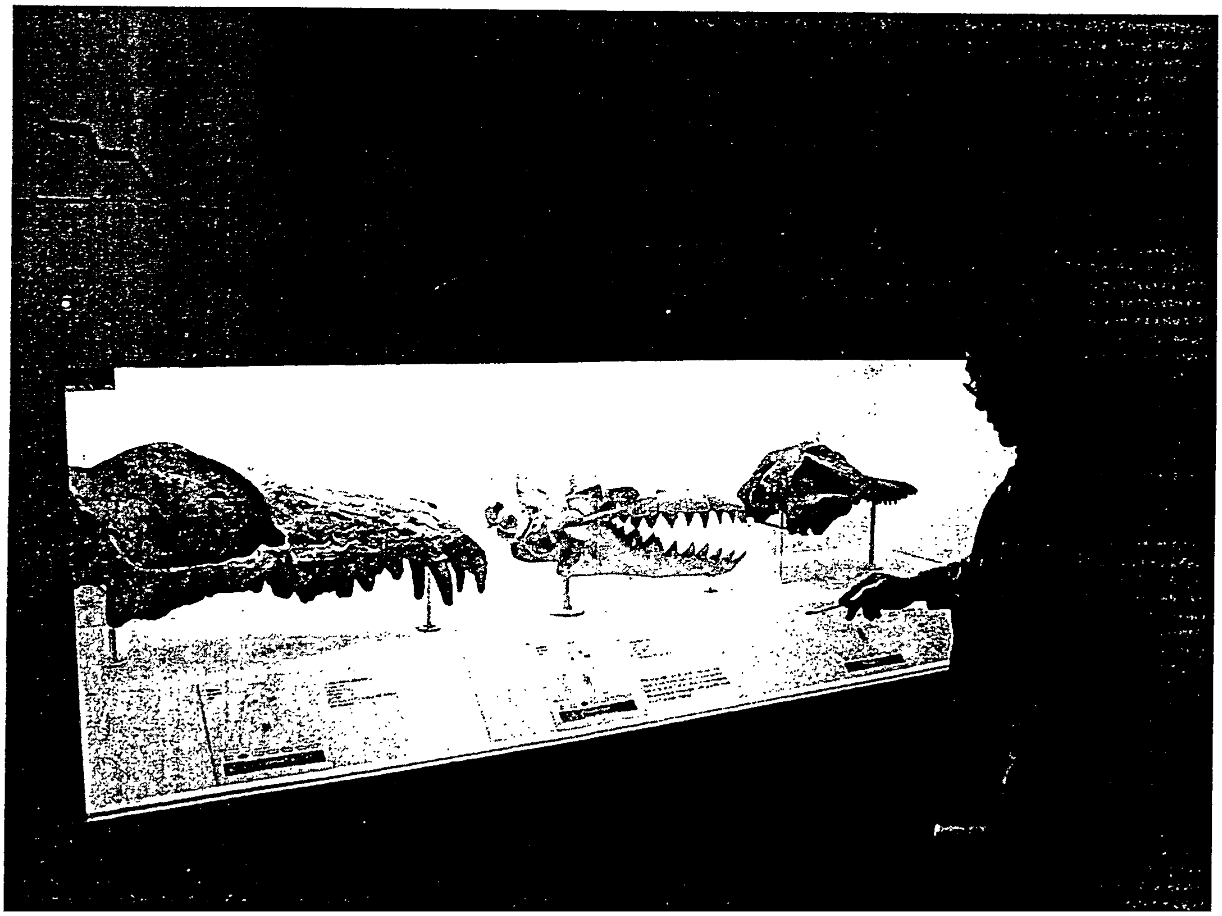

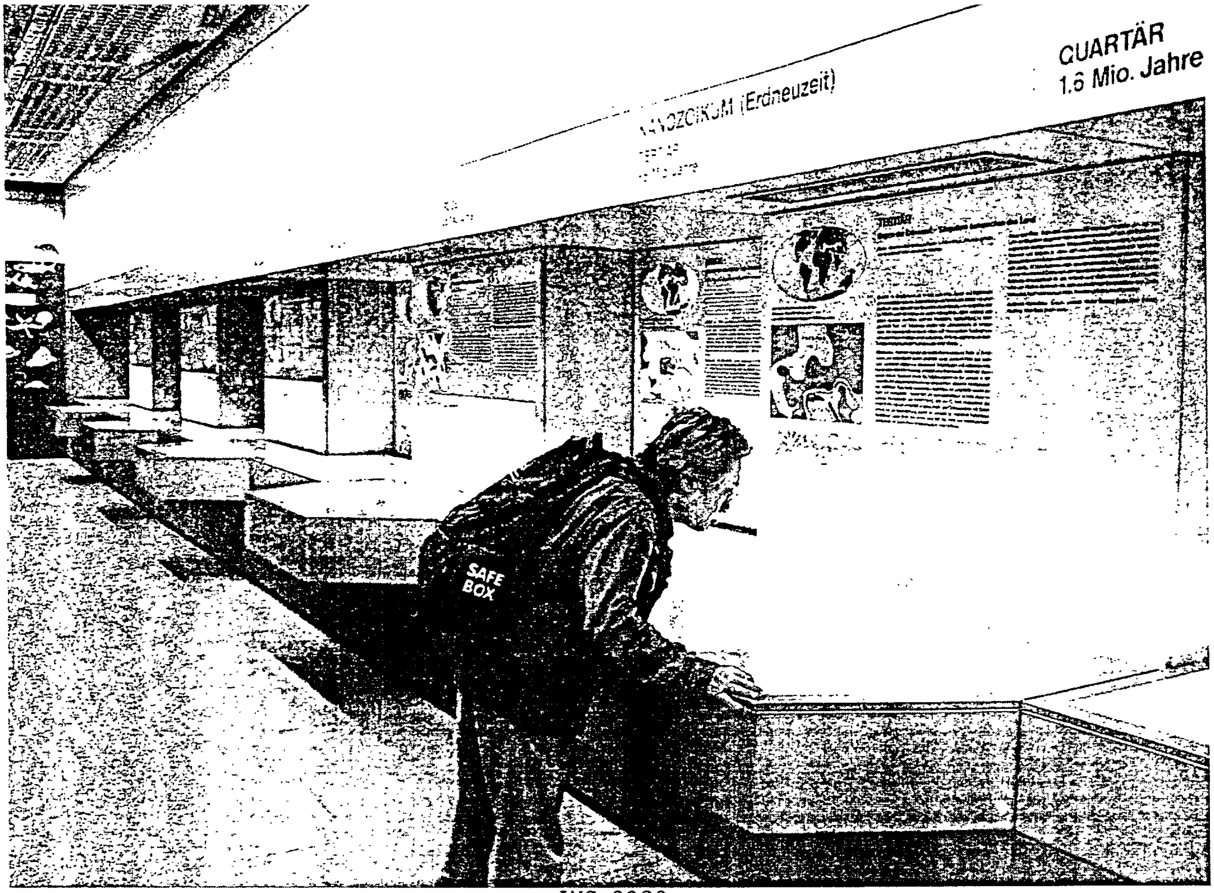
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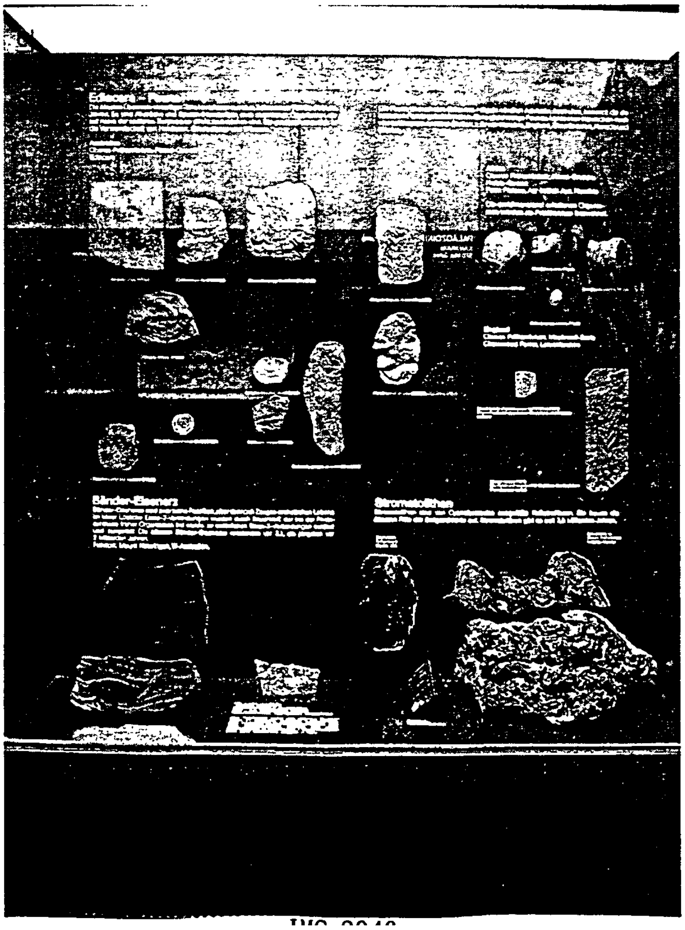
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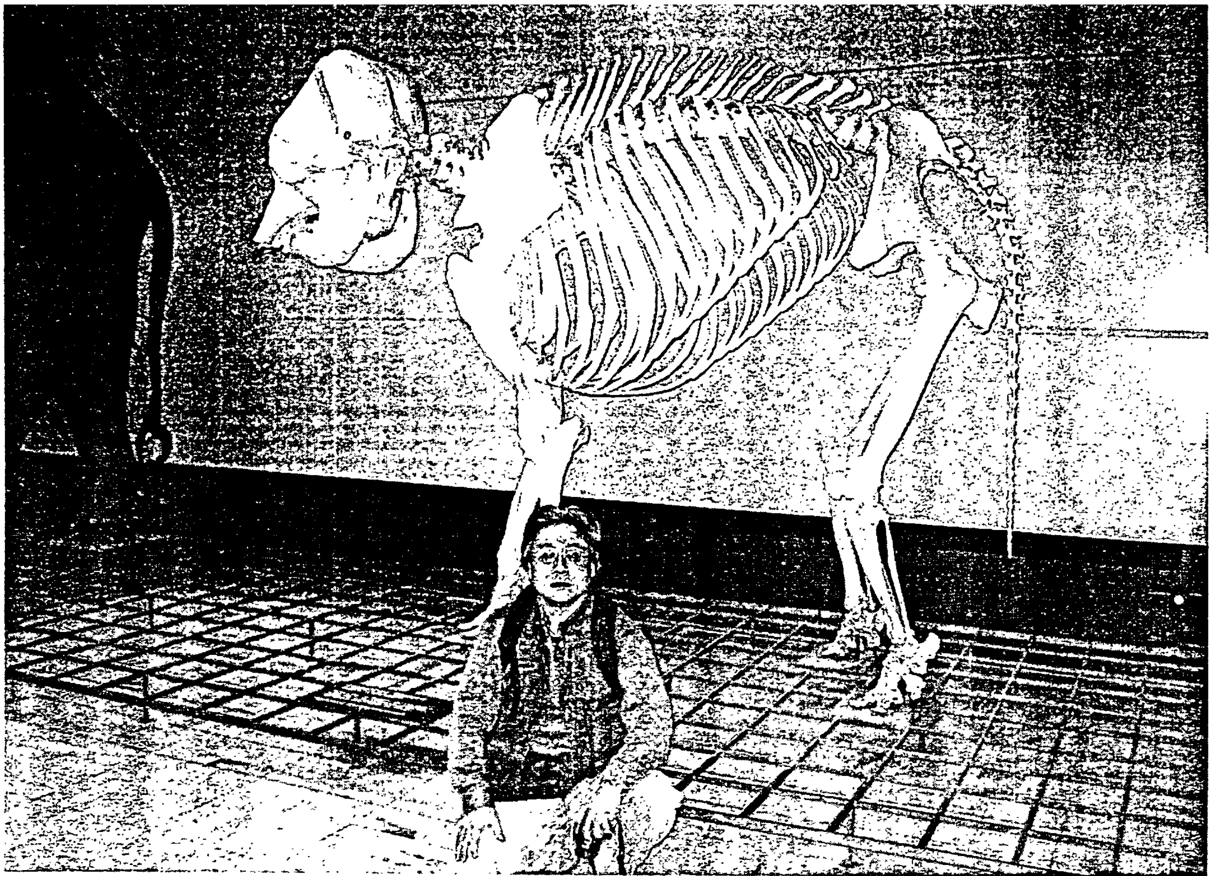

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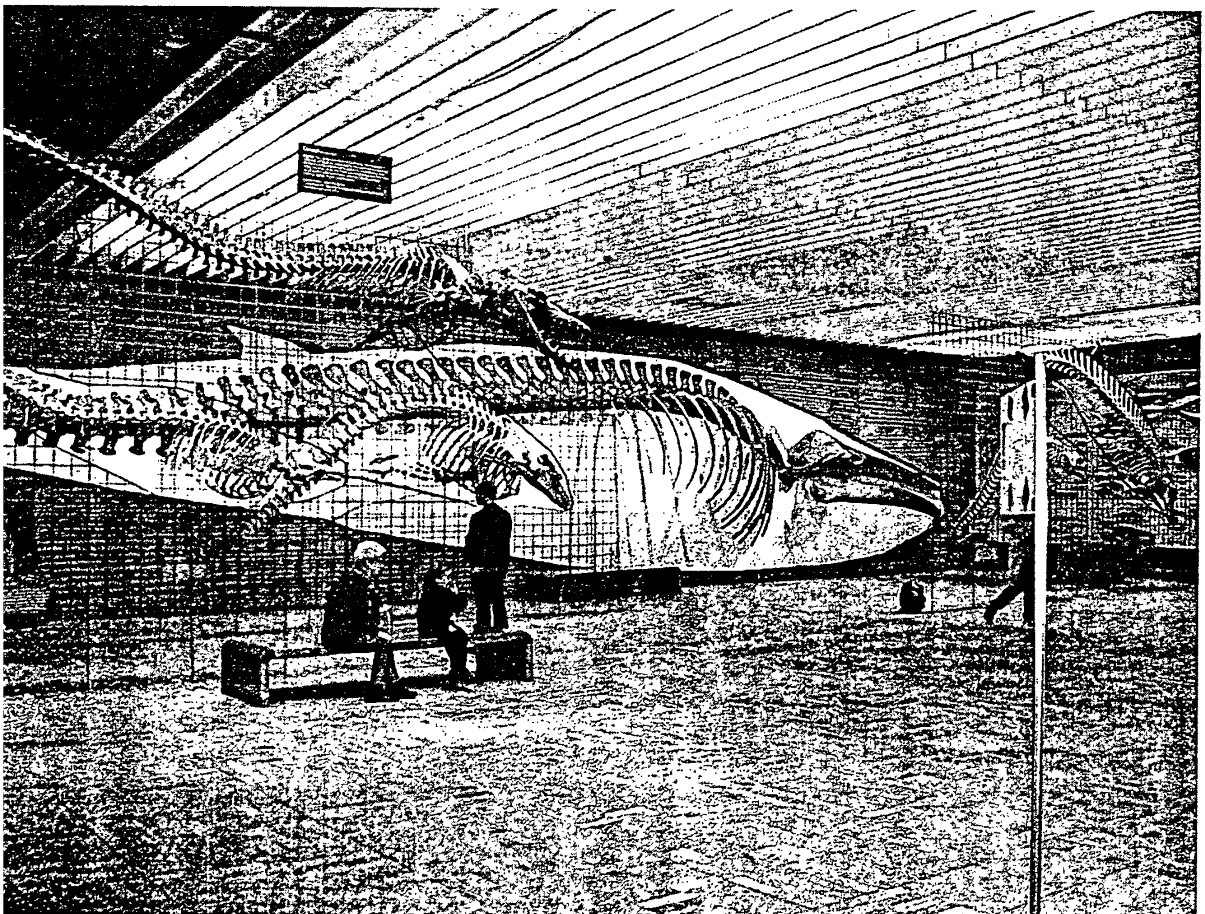

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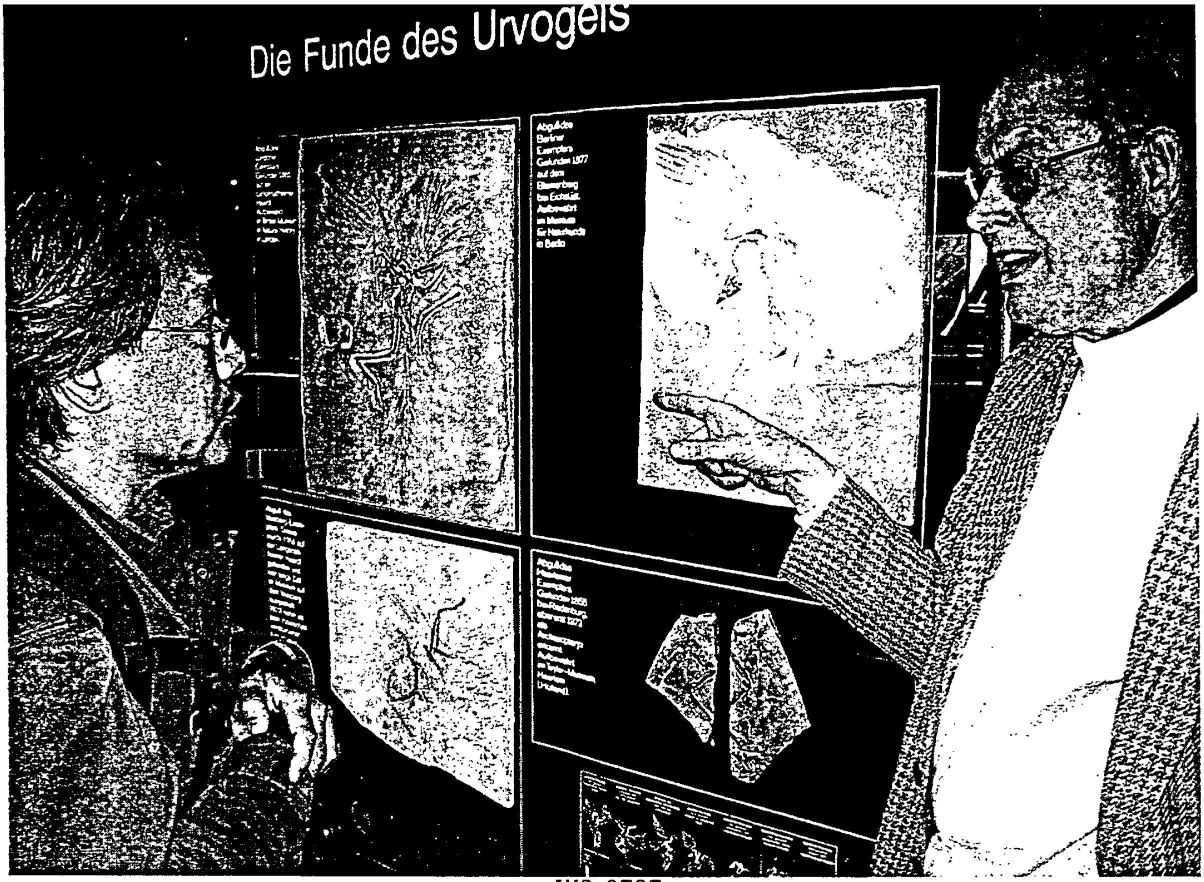

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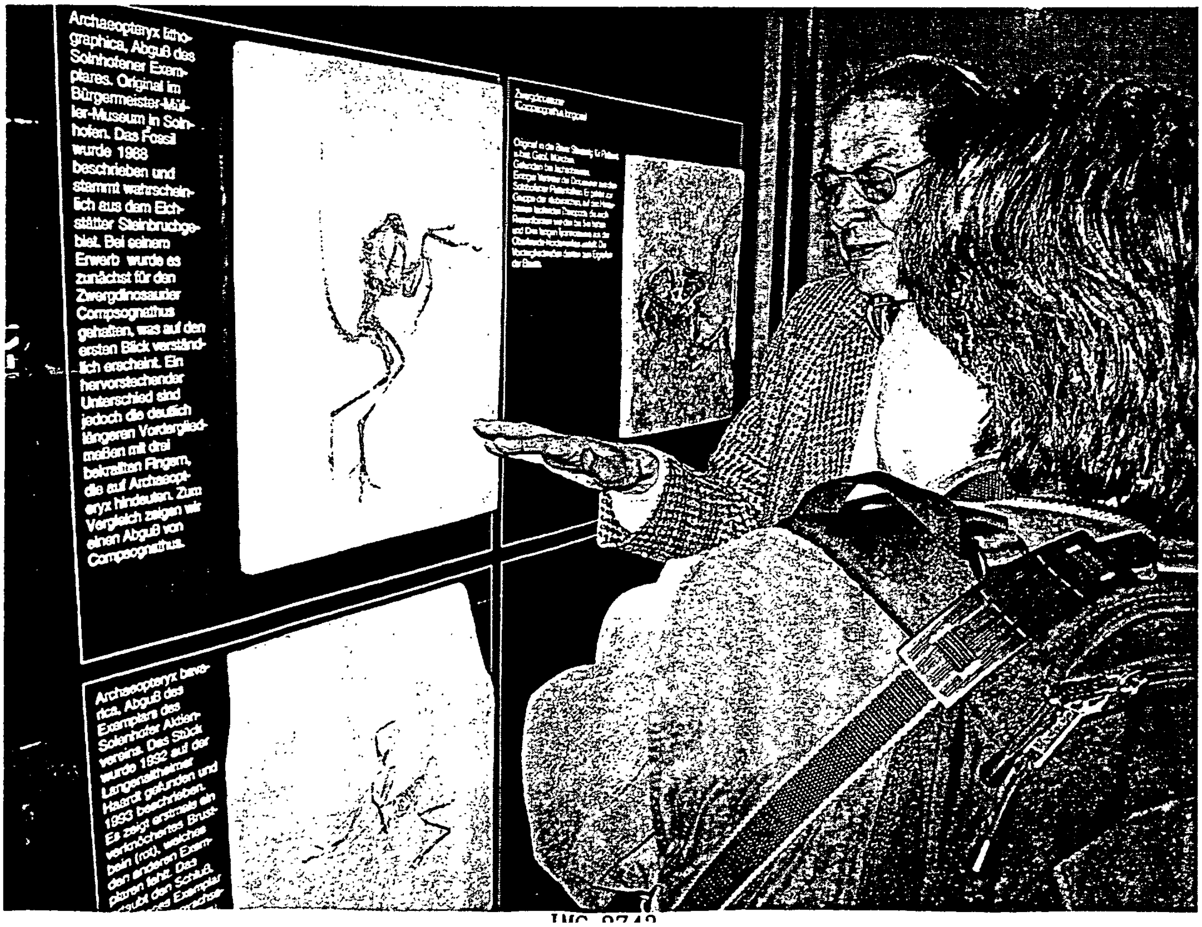

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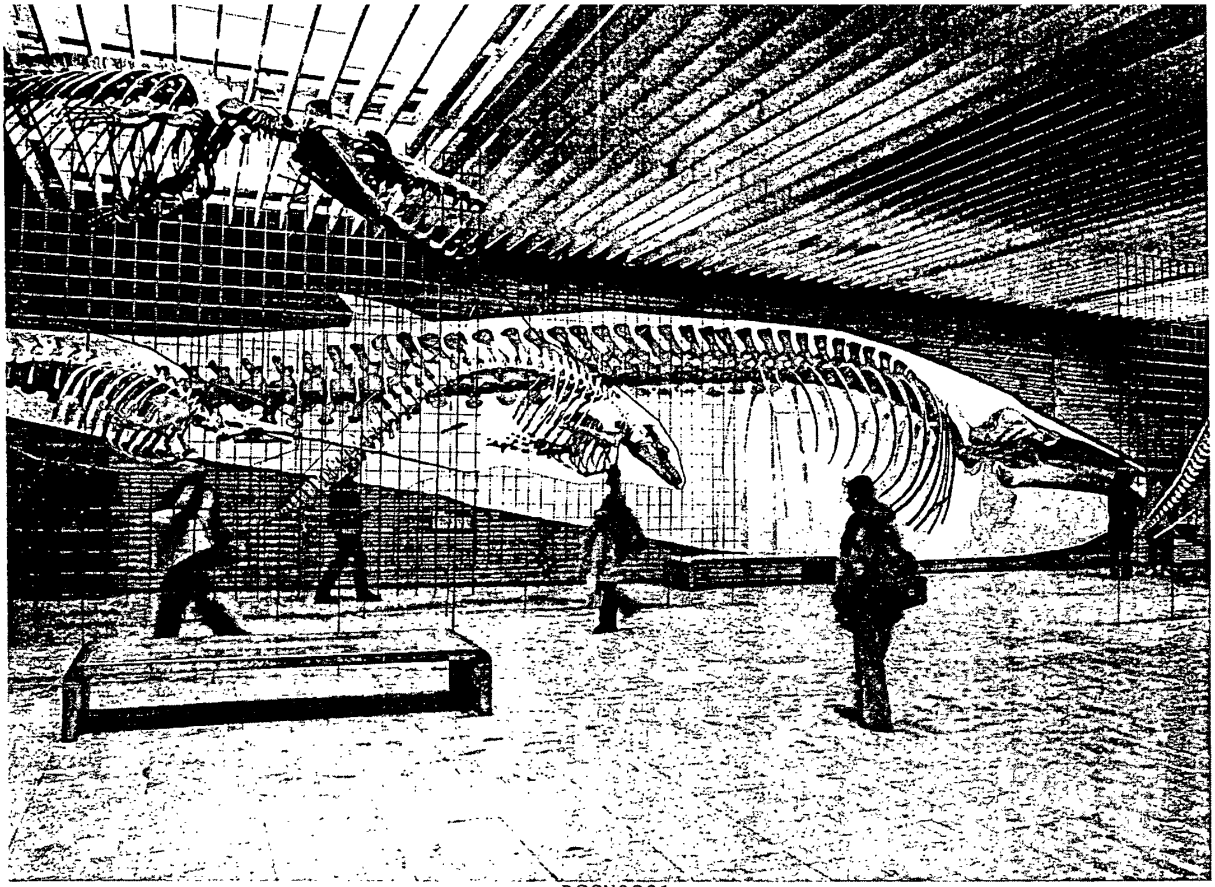

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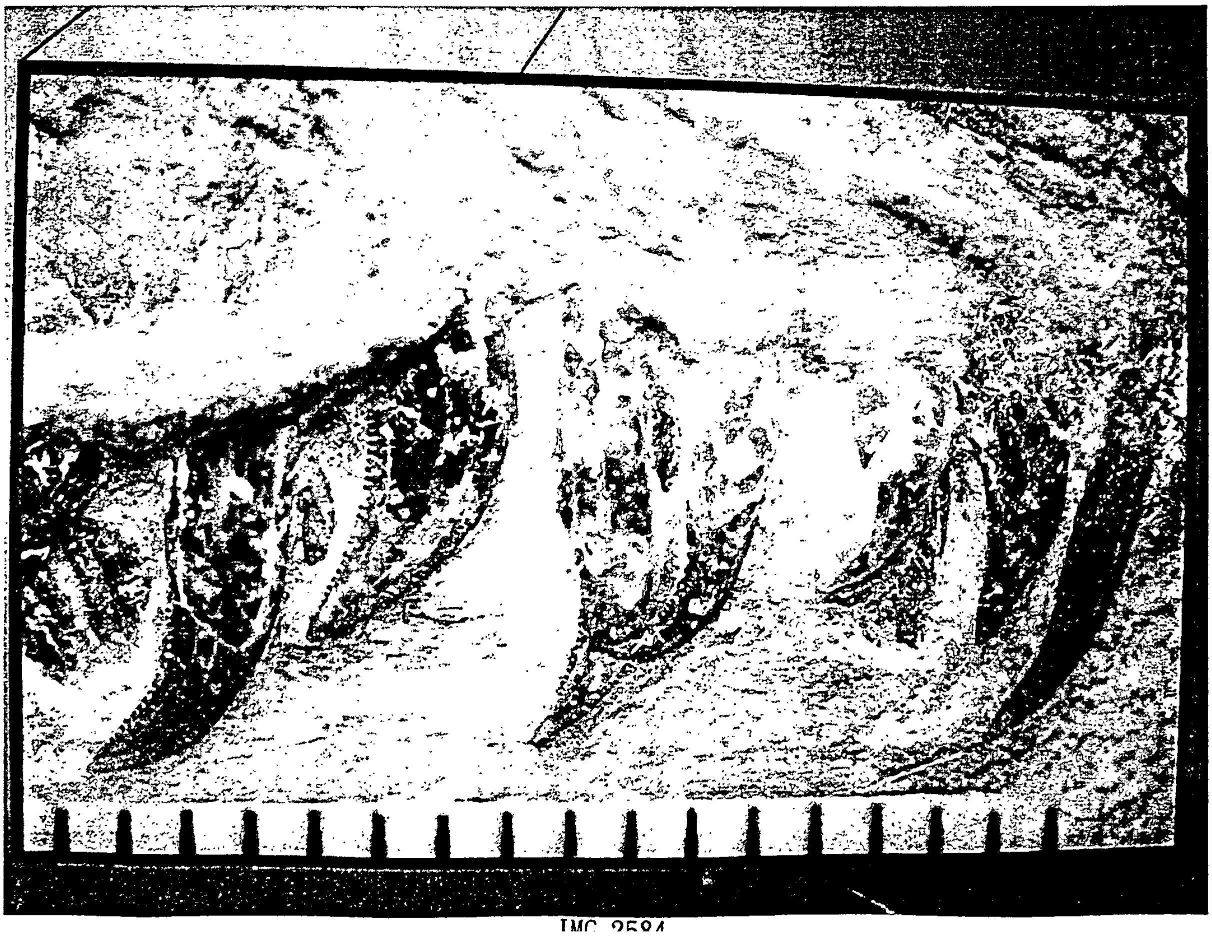

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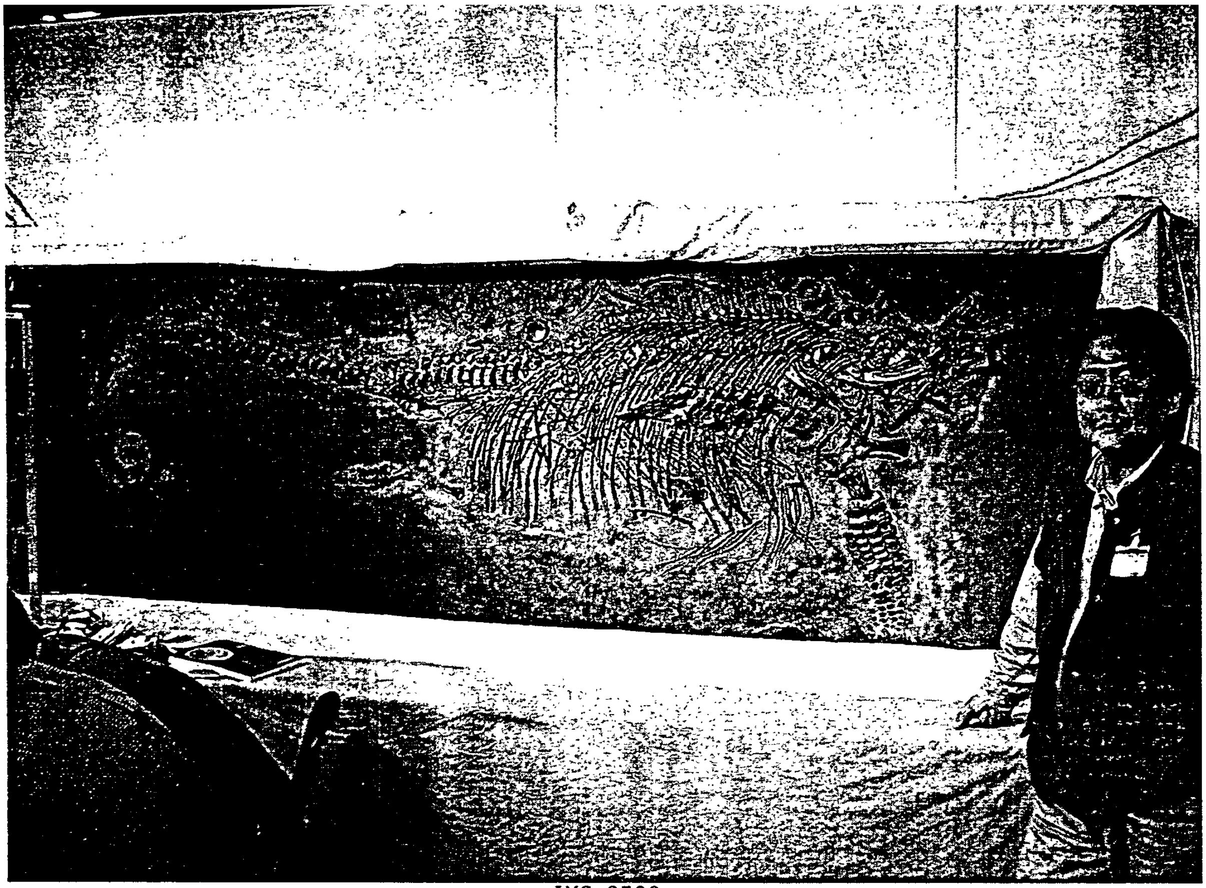

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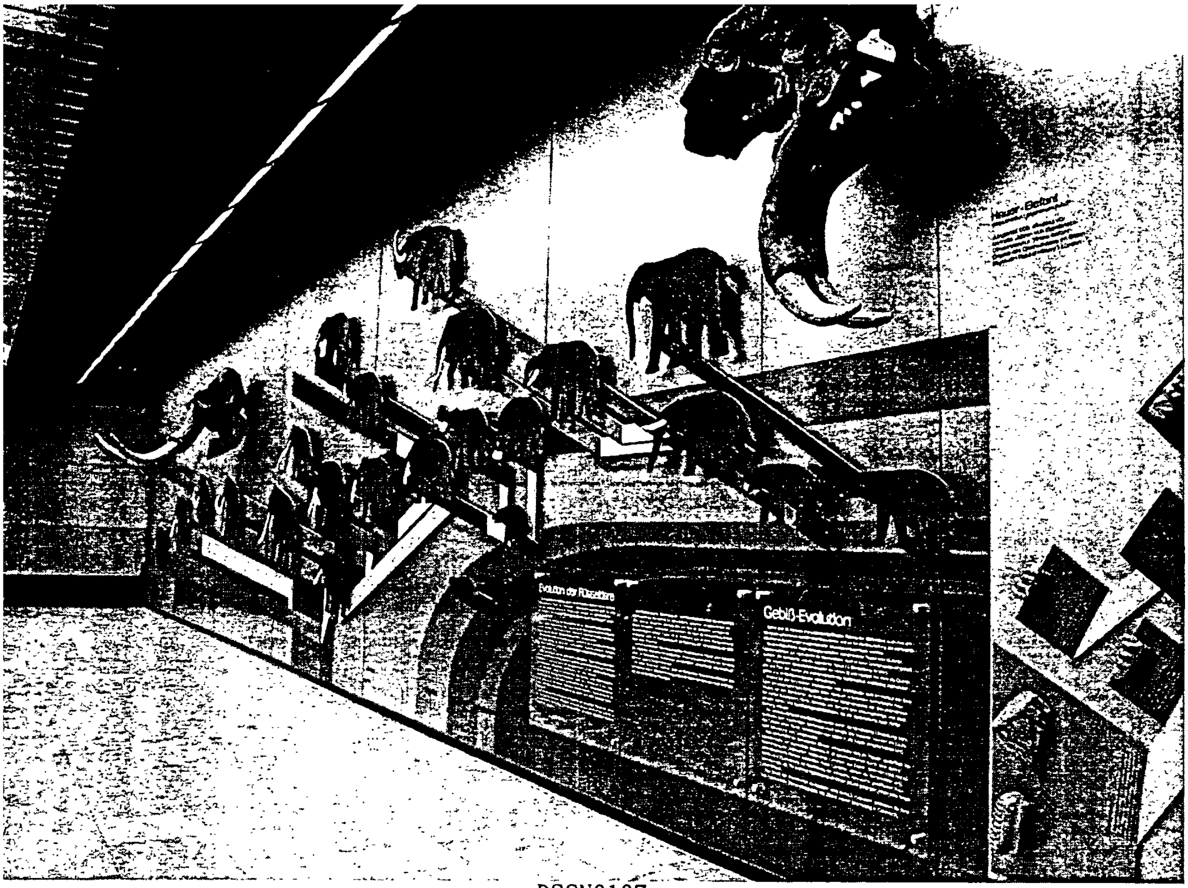

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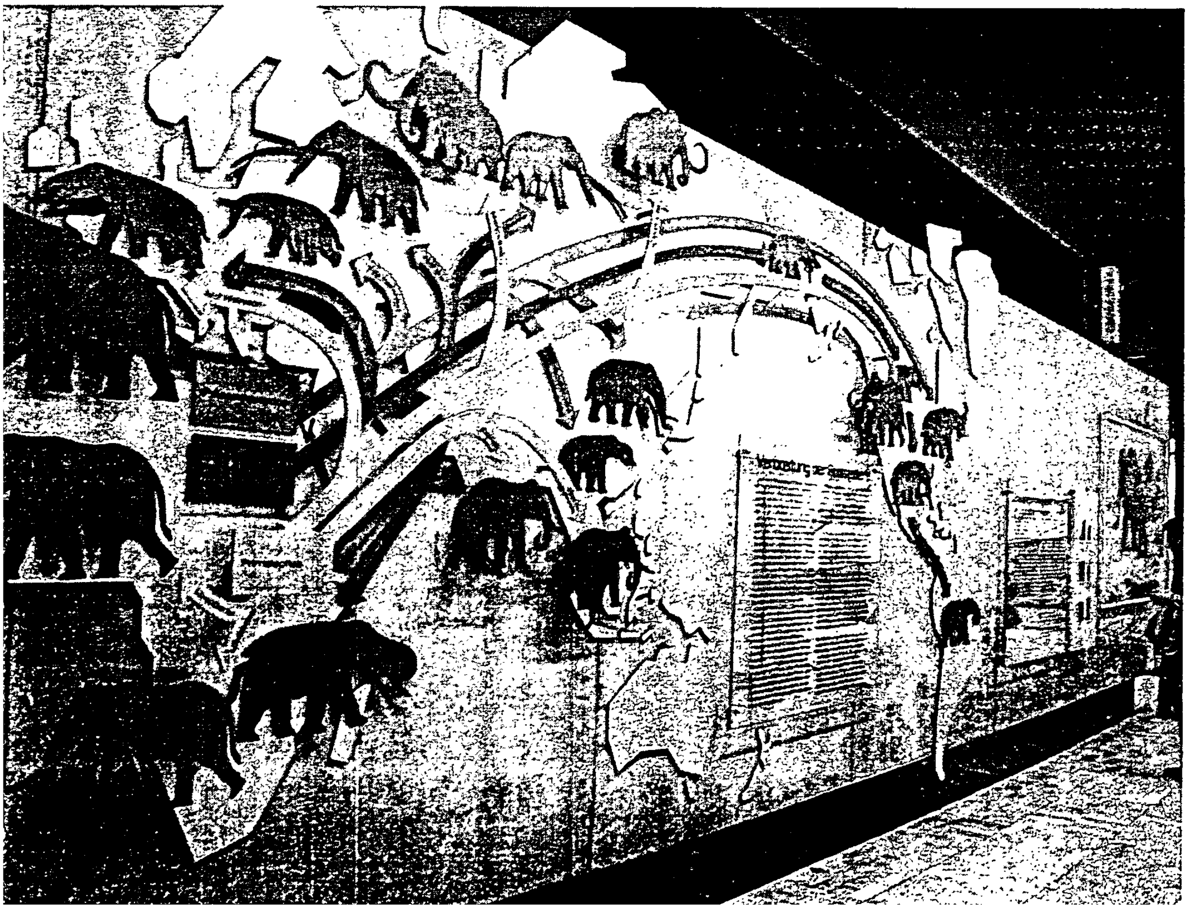

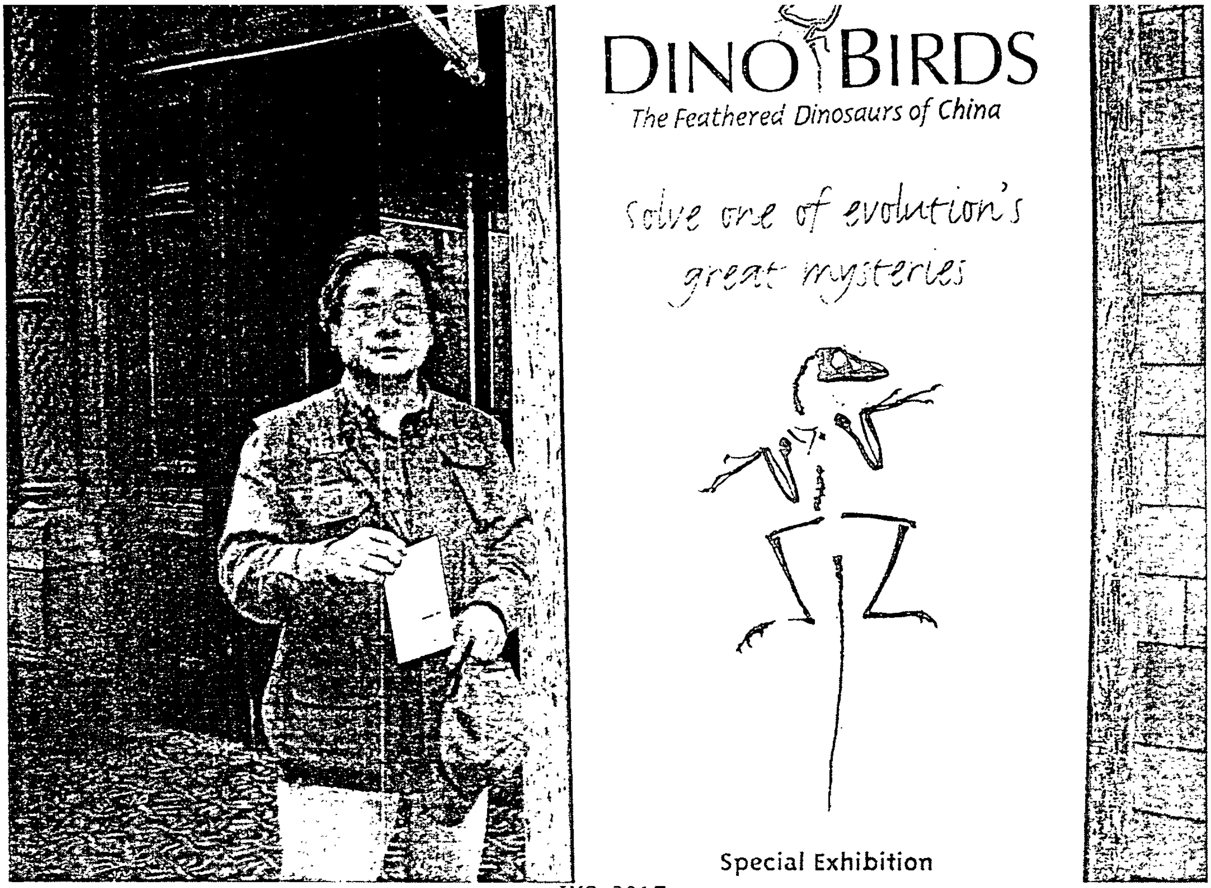

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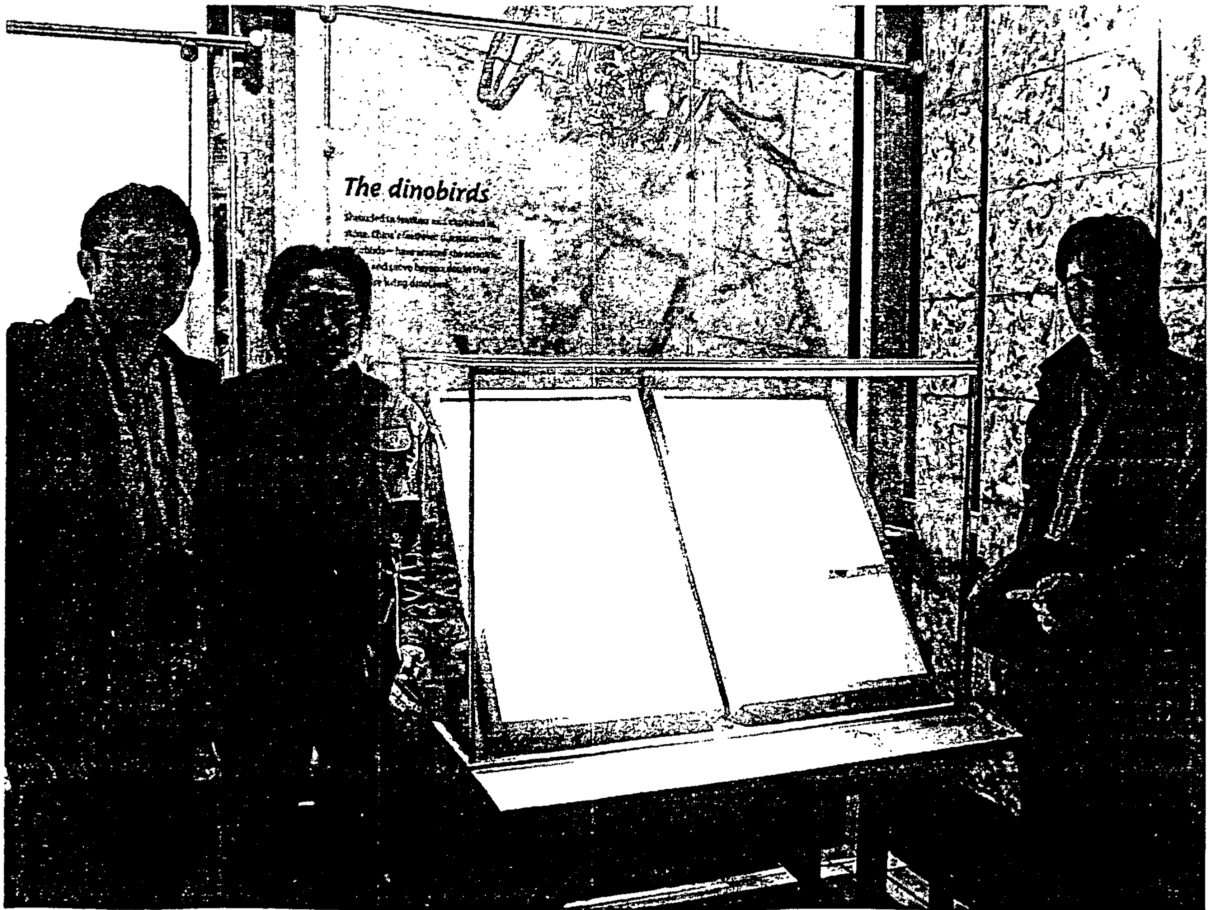

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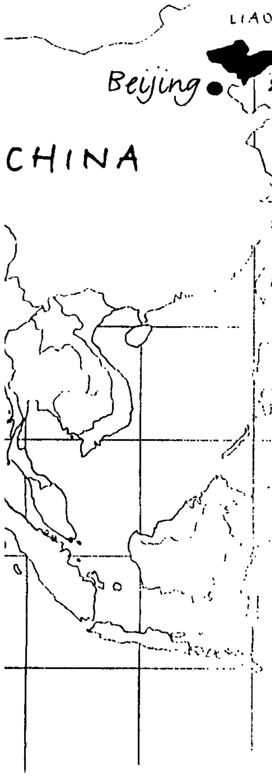
Chinese treasures

In 1996, farmer fossil hunters in Liaoning province, northeast China, found some completely unexpected bones. While sifting through the usual fish and reptile fossils commonly found in the area, a 124-million-year-old dinosaur was discovered.
It marked the beginning of a startling journey of discovery. Fossils found soon after would confirm a theory that has been argued for more than 100 years. Now on display in London for the first time, their story can at last be told.



A working quarry site in Liaoning.

Cover image: 'Fuzzy raptor' – a feathered dromaeosaur © Mark Norrell, Mick Ellison, Keqin Gao, AMNH
Designed by the Computer Graphic Services CGS0833

Tickets

£5, £3 concessions,
£12 family, free to under 5s and Members.
Book online at
www.nhm.ac.uk/dinobirds

Open

18 July 2002 – 5 May 2003
Monday to Saturday
10.00–17.50
Sunday 11.00–17.50
(last admission 17.30)
Open on Bank Holidays,
closed 24–26 December

Exploring the Museum

Dino-Birds is ideal for adults and for families with children over seven. You can find out more about birds and their ancestors during your visit in the Museum's *Birds* and *Dinosaurs* exhibitions, where you can come face to face with a moving, breathing *T. rex*, while the *Origin of Species* Gallery explores Charles Darwin's theory of evolution.

Membership

Members enjoy free entry to Special Exhibitions, a free quarterly magazine, workshops and behind-the-scenes tours. To join, call **020 7942 5792** or pick up a leaflet from the Museum's information desks.

Gifts and refreshments

A wide range of gifts and souvenirs are on sale in the Museum's shops. Hot and cold meals are available from the Life Galleries Restaurant, while our cafés and snack bar offer light refreshments.

Events and activities

For details of *Dino-Birds* events and activities, contact Education on
020 7942 5555 or visit
www.nhm.ac.uk/education

Disabled visitors

Wheelchair access via Earth Galleries entrance in Exhibition Road. Pre-bookable disabled parking **020 7942 5888** (24hrs). For travel information or advice call Tripscope on
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⊖ South Kensington
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In collaboration with The Geological Museum of China

THE NATURAL HISTORY MUSEUM

DINO BIRDS

The Feathered Dinosaurs of China

18 July 2002 – 5 May 2003

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DINO BIRDS

The Feathered Dinosaurs of China

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Exhibition hours

Monday–Saturday 10.00–17.50
Sunday 11.00–17.50
(Last admission 17.30)
18 July 2002 – 5 May 2003
Closed 24–26 December

Admission

£5, £3 concessions, £12 family, free to under 5s and Members.

More exhibitions

The Museum runs a programme of Special Exhibitions throughout the year.

Turbulent Landscapes
Until 15 Sept 2002
Play with the forces of nature in this interactive exhibition where you can create whirlpools, tornadoes and sand dunes.

Joint ticket
Save money and buy a joint ticket to *Dino-Birds* and *Turbulent Landscapes*: £7, £4 concessions, £16 family, free to under 5s and Members.

BG Wildlife Photographer of the Year 2002
19 Oct 2002 – spring 2003
An exhibition of winning entries from the world's largest and most prestigious wildlife photography competition.

Events and activities

For details of events and activities related to *Dino-Birds*, contact Education Bookings on 020 7942 5555 or visit www.nhm.ac.uk/education

Museum shops

A wide range of gifts, books, postcards and posters are on sale in the Museum's shops, including a range of gifts inspired by the *Dino-Birds* exhibition.

Publications

A special book has been produced to coincide with the exhibition. Priced £5.95, *Dino-Birds: From Dinosaurs to Birds* has been written by Dr Angela Milner, The Natural History Museum's dinosaur expert. Available from October 2002 at all good bookshops or direct from Plymbridge Distributors on 01752 202 301.

Museum cafés

Hot and cold meals are available in the Life Galleries Restaurant, while our cafés and snack bar offer light refreshments. Look out for special Chinese-themed menus.

Online

Visit www.nhm.ac.uk/dinobirds for more information about the exhibition.

2

On tour

Dino-Birds: The Feathered Dinosaurs of China will be touring a number of major museums in Europe from summer 2003.

The Natural History Museum,
Cromwell Road, London SW7 5BD
Tel: 020 7942 5000
www.nhm.ac.uk

借屍還魂。

Cover image: 'Fuzzy raptor' – a feathered dromaeosaur © Mark Norell, Mick Ellison, Keqin Gao, AMNH. Designed by the Computer Graphic Services CGS0833

展示設計超群

THE NATURAL HISTORY MUSEUM

中国地质博物馆

In collaboration with The Geological Museum of Chi...

For more than 140 years scientists have argued modern birds were linked to dinosaurs. In 2000, farmers in Liaoning, northeast China unearthed the final proof, a 124-million-year-old predatory dinosaur outlined in feathers, affectionately named 'Fuzzy raptor'. It had the bony skeleton expected of a predatory dinosaur closely related to birds, but was fringed with a coat of feathers. This exciting discovery solved one of nature's mysteries – how birds evolved from meat-eating dinosaurs.

In *Dino-birds*, internationally renowned dinosaur expert Angela Milner unravels the story linking dinosaurs to birds, from the astonishing discovery of *Archaeopteryx* in 1861 – the most ancient bird known – to the feathered dinosaurs of China. Looking at the people involved and the debates that ensued, she covers the development of fluffy coverings to feathers for flight and compares ancient birds to the modern fliers. It is certain you will never look at birds in quite the same way.

THE NATURAL HISTORY MUSEUM

ISBN 0-565-09174-3
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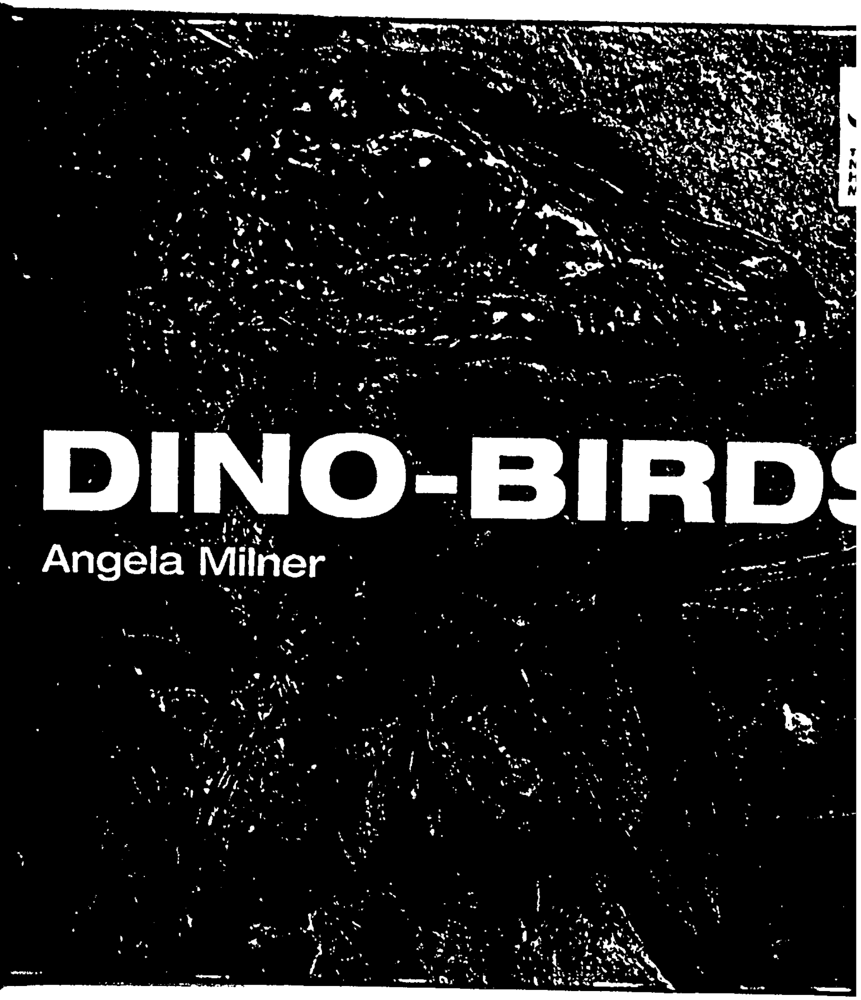
DINO-BIRDS

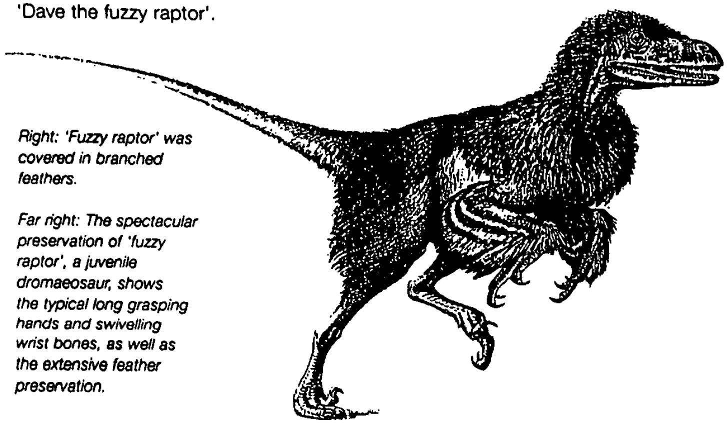
THE NATURAL HISTORY MUSEUM



DINO-BIRDS

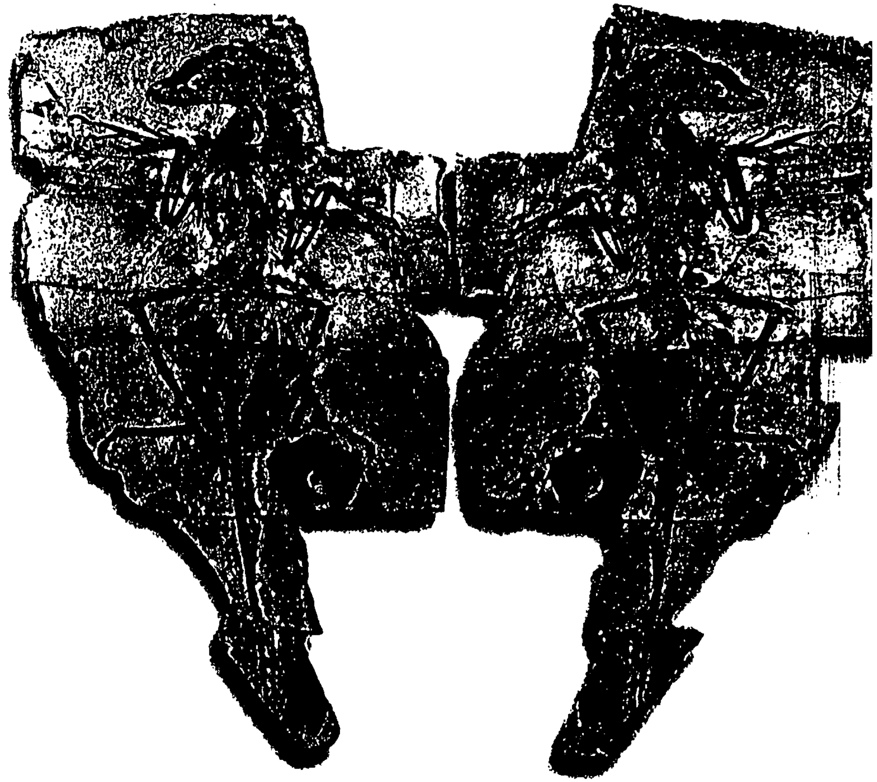
Angela Milner

Sinornithosaurus, found in 1998 confirmed that the family closest to *Archaeopteryx* were feather covered; just what we would expect to find. Perhaps the most stunning dino-bird of them all was a juvenile dromaeosaur discovered in 2000. It was covered from head to tail in fine branched feathers and is affectionately known as 'Dave the fuzzy raptor'.



Right: 'Fuzzy raptor' was covered in branched feathers.

Far right: The spectacular preservation of 'fuzzy raptor', a juvenile dromaeosaur, shows the typical long grasping hands and swivelling wrist bones, as well as the extensive feather preservation.



Welcome to The Natural History Museum.
The Museum offers visitors of all ages a wide variety of lively and stimulating exhibitions about the natural world. It is also an important scientific centre, researching the diversity of nature.
You can discover more about this work in the new Darwin Centre.

Darwin Centre

Phase One now open

Life Galleries

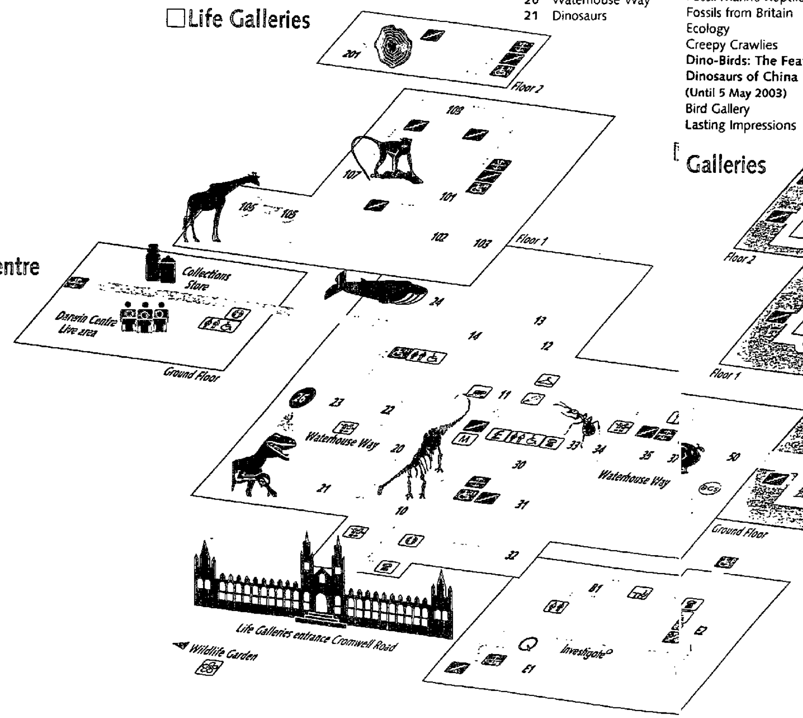
Ground Floor
10 Wonders of The Natur History Museum
12 Fishes, Amphibians and Reptiles
13 Marine Invertebrates
14 **Rompicollo**
(22 October 2002 – 5 January 2003)
20 Waterhouse Way
21 Dinosaurs

Human Biology
Mammals
Mammals
Blue Whale
BG Wildlife
Photographer of the Year
(19 October 2002 – 5 May 2003)
Waterhouse Way,
Fossil Marine Reptiles
Fossils from Britain
Ecology
Creepy Crawlies
Dino-Birds: The Feathered Dinosaurs of China
(Until 5 May 2003)
Bird Gallery
Lasting Impressions

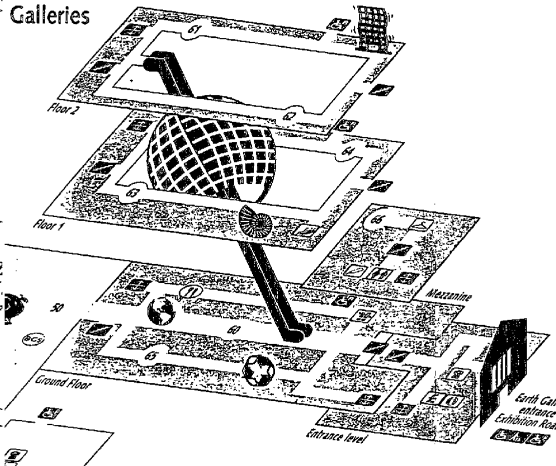
Floor 1
101 Our Place in Evolution
102 Minerals
103 Meteorites
105 Origin of Species
106 The Rowland Ward Pavilion African Mammals
107 Primates
108 Plant Power

Floor 2
201 Giant Sequoia

Basement
Clore Education Centre
Q **Investigate**
(ideal for 7–14 yrs)
Mon to Fri 14.30–17.00
Sat 10.30–17.00
Sun 11.30–17.00
During school holidays:
Mon to Fri 10.30–17.00
Last admission 16.30
B1 Picnic Area, schools reception desk
E1 Education room 1
E2 Education room 2
E3 Education room 3



Galleries



Traces
A new earth-science art exhibition by Paul Rosenbloom.
Displays throughout the Museum until 24 March 2003.

Earth Galleries

Ground Floor
60 Visions of Earth
65 Earth Today and Tomorrow

Mezzanine
66 Earth Lab

Floor 1
63 From the Beginning
64 Earth's Treasury

Floor 2
61 The Power Within
62 Restless Surface

Key

- Toilet facilities
- Accessible toilets
- Baby Feeding & Changing Rooms
- Cloakrooms
- Information Desks
- Meeting Point (Gallery 10)
- Shop
- Life Galleries Restaurant (Gallery 35)
- Globe Café (Gallery 60)
- Waterhouse Café (Gallery 11)
- Snack Bar (Basement)
- Picnic Area (Basement)
- Flett Events Theatre (Earth Galleries, Floor 1)
- Telephones
- British Geological Survey Information Office
- Stairs
- Lifts
- Accessible Entrance
- Accessible Parking
- Safe Refuge Area
- Cash machine
- Wildlife Garden
  Open May – November
  Special interest group visits may be pre-arranged outside these times – for details please ask at the information desks

Special Exhibitions

Dino-Birds: The Feathered Dinosaurs of China
Until 5 May 2003

Did all the dinosaurs become extinct or did some evolve into birds? *Dino-Birds* reveals, for the first time in Europe, 13 amazing fossils that confirm the long-debated view that birds are the living descendants of dinosaurs. The exhibition features the original 124-million-year-old 'Fuzzy raptor' fossil plus 12 other dinobird fossils, some being the only example of their particular species in existence.
Gallery 38

BG Wildlife Photographer of the Year 2002
19 October 2002 – 5 May 2003

A leopard resting on a tree, juvenile rats drinking from a water butt, elephants crossing, windswept cottongrass... the most beautiful images of our world have been captured on film in this celebrated annual exhibition.
Jerwood Gallery (26)

Hanuman langurs © Jean-Pierre Zwaenepoel (Belgium). From the *BG Wildlife Photographer of the Year* exhibition.

The missing link? 'Fuzzy raptor' – an intriguing fossil from the *Dino-Birds* exhibition.

Exhibition tickets: £5, concession £3 (includes children 5–16, over 60s, ES40 holders and students), family £12 (up to two adults and three children), children under 5 and Members free.

Saver tickets for both exhibitions: adult £8, concession £4.50, family £18.

Groups: pre-booked groups of 10+ save 50p per person. Pre-booked school groups go free. Group booking number **020 7942 5555**.

Traces
Until 24 March 2003

A new earth-science art exhibition by Paul Rosenbloom, inspired by the Museum's collection of graptolites – 325-million-year-old fossil remains of extinct zooplankton.
Displays throughout the Museum

Rompicollo
22 October 2002 – 5 January 2003

An exhibition of textiles inspired by the Museum's collection of fossilised dinosaur skin imprints.
Gallery 14

Museum and Wildlife Garden Guided Tours

For details of tours please ask at the information desks. Personal tours can be arranged by calling **020 7942 5420**.

The Darwin Centre

Inspiring discovery of the natural world

For nearly 250 years, The Natural History Museum has been making scientific discoveries that shape our understanding of the natural world. Now, for the first time, the new Darwin Centre throws open the doors to the work of the Museum's 350 scientists and reveals the millions of specimens that underpin their work.

Phase One now open

Phase One of the Darwin Centre houses 22 million zoology specimens. You can tour this vast collection, meet the scientists who work with it, and discover more about their fascinating research into the diversity of the natural world. The entrance to the Darwin Centre is through the *Mammals* galleries (23 & 24 on the map).

Darwin Centre Explore

Go behind the scenes on one of these regular 35-minute tours. To find out more and book your free tour, visit the information desks in the Life Galleries, Earth Galleries or the Darwin Centre.

Darwin Centre Live

Meet scientists seven days a week and find out about their work.
In the first season of events you can:

- find out about *Extreme Environments* – from volcanoes, canyons and floods on Mars to the deep ocean
- discuss *Our Changing World*, pollution and climate change
- explore *Collectors and Collecting* and how scientists find and identify new species
- see *Under the Microscope* and view scientists in research areas throughout the Museum
- discuss and debate areas of Museum science that are *In the Headlines*

Next steps

Phase Two of the Darwin Centre will house 28 million insects and six million plants. It is due to open in 2007, but to take the final steps we need your help. To discuss opportunities for tax-effective giving at all levels, please contact Development on **020 7942 5890** or email **supporter@nhm.ac.uk**

Information

Opening hours

Monday–Saturday 10.00–17.50
Sunday 11.00–17.50
Last admission 17.30
Closed 24–26 December
Admission to the Museum is free
Children under 12 must be accompanied by an adult.

Gifts and refreshments

A wide range of gifts, books, postcards and posters are on sale in the Museum's shops. Hot and cold meals are available from the Life Galleries Restaurant, while our cafés and snack bar offer light refreshments.

Finding out more

- touch screen information points are located in the Central Hall (Gallery 10) and Gallery 60
- Souvenir Guides are on sale at admissions points, information desks and in the shops
- Activity Guides are on sale in the shops and from the information desks
- for details of our events and activities programme, contact Education on **020 7942 5555** or visit the website at **www.nhm.ac.uk/education**
- for details of day and evening courses and field study tours for adults, contact Education on **020 7942 5555**
- teachers planning school visits can contact Education on **020 7942 5045** (12.00–13.00 weekdays, term time) or email **education@nhm.ac.uk**

Access for disabled visitors

We are working to improve the accessibility of our heritage building.

- guide dogs are welcome
- wheelchairs available for loan, please ask at the information desks
- to check availability of programmed signed performances and explainers with signing skills, please call **020 7942 5555**
- the information desks, Darwin Centre Live space and Flett Events Theatre are provided with induction loops
- for tours, neck loops are available for people with partial hearing
- limited pre-bookable parking spaces available for disabled visitors. Call **020 7942 5888** (24hr service)
- for travel information/advice call Tripscope on **08457 585 641** or email tripscope@cablenet.co.uk

If you have particular requirements in the event of an emergency evacuation, please contact the information desk on arrival.

Membership

Benefits of Natural History Museum Membership include a free quarterly magazine, events and behind-the-scenes tours, children's workshops and free admission to Special Exhibitions. To join, pick up a leaflet from the information desks or contact Membership on **020 7942 5792**.

Supporting the Museum's work

The Museum relies upon public funds to undertake its work. We are grateful for the continued support we receive from our friends, visitors, sponsors and donors. To find out more about making a donation or leaving a legacy, contact Development on **020 7942 5266**. For further information about how your company can become involved, contact **020 7942 5906**.

Photography

Photography or video filming for commercial purposes, reproduction or broadcast in any medium is not permitted unless by prior agreement. The use of tripods is not permitted.

Comments welcome

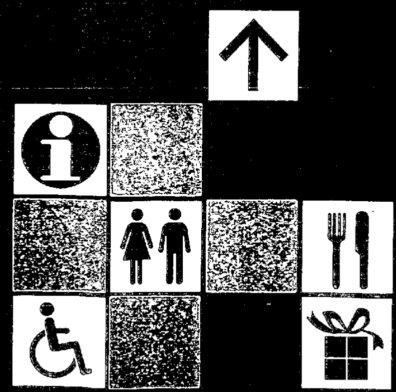
Your comments and suggestions are always welcome and can be made either on the questionnaire attached, at the information desks or to Deirdre Candlin, Director of Visitor and Operational Services.

The Natural History Museum
Cromwell Road, London SW7 5BD
Tel 020 7942 5000
www.nhm.ac.uk

Sept 2002. CCS0904

THE NATURAL HISTORY MUSEUM

map



Dear Visitor,

I very much hope that you found your visit to The Natural History Museum interesting, but your enjoyment need not end here. By becoming a member you could play an important role.

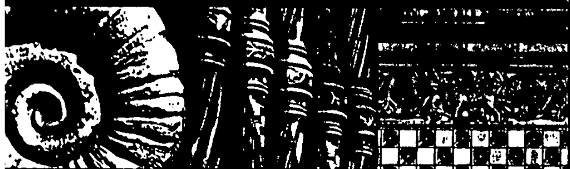
There is so much to the Museum, and after ten years as Director, I continue to be not only impressed but truly amazed by the diversity of research and educational activity that is carried out here. Membership offers special access to this work and what's more, as a member you will also be making your own personal commitment to the natural world.

Membership offers unique involvement with The Natural History Museum – please consider joining us.

Neil Chalmers

Neil Chalmers
Director

The Natural History Museum



The Natural History Museum building has been described as a 'cathedral to the natural world'. It is a stunning structure both internally and externally and as a member you can enjoy its many facilities time and time again. In addition, through your support, you will be making an important contribution to Museum funds, ensuring the building and the important work carried out in it continues to be supported.

Membership Offers many privileges


Free entry

Free admission to The Natural History Museum as well as The Walter Rothschild Zoological Museum Collection at Tring, Hertfordshire


Magazine

A quarterly, full colour magazine, offering insight into the Museum's discoveries in the natural world as well as updating you on events and exhibitions


Events

A fascinating range of events including behind the scenes tours to exhibition previews and children's workshops


A place of your own

The members' room offers a chance to relax and enjoy free refreshments during your visit to the Museum

10% discount at the Museum's shops and restaurants

excluding Basement Snack Bar

Your special role

In addition to the many privileges you will gain as a member, through your subscription, you will be making your own personal contribution to the natural world.

0031

THE NATURAL HISTORY MUSEUM

join TODAY

MEMBERSHIP

Your commitment to the natural world

A Unique Experience

During a visit to the Darwin Centre you can:

- **view fascinating and historic specimens never seen by the public before**
- **use touch screens to learn about the Museum's science and its importance today**
- **take guided tours among the vast collections**
- **meet the Museum's scientists**

There are fourteen Darwin Centre *Explore* tours of the collection each day, plus Darwin Centre *Live* events with scientists daily at 11.30 and 14.30. Places can be booked on arrival at the Museum. A limited number of tickets are available in advance at www.nhm.ac.uk/darwincentre (booking fee). Tours are suitable for adults and children aged 10 or over.

For a full events listing, or more information about the Darwin Centre, visit www.nhm.ac.uk/darwincentre or call 020 7942 5000.

Design: Computer Graphic Service of The Natural History Museum CGS 0926

Darwin Centre Phase Two

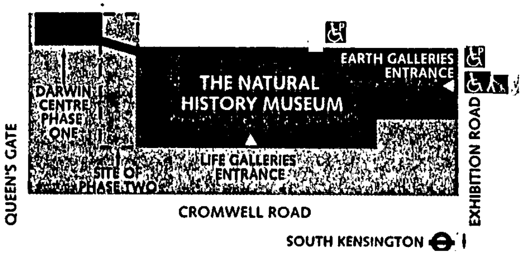
Darwin Centre Phase Two is now being planned and is scheduled to open in 2007. Phase Two will house The Natural History Museum's Entomology and Botany collections comprising 28 million insects and six million plants. A fundraising campaign is now underway and supporters include the Wellcome Trust, the Heritage Lottery Fund, the Garfield Weston Foundation and GlaxoSmithKline. If you would like to contribute to the Phase Two campaign, please contact the Development Office on 020 7942 5890.

THE WELLCOME TRUST

Heritage Lottery Fund

Visiting Information

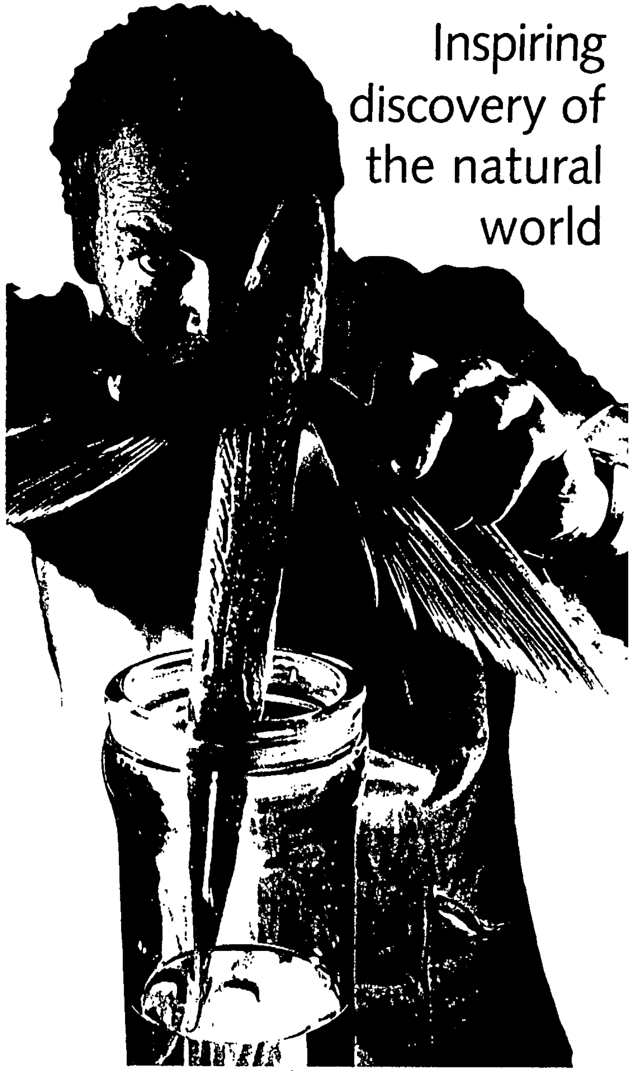
Admission to the Darwin Centre, including tours and events, is free.
Entry is through the main Museum.
Opening hours: Monday – Saturday 10.00-17.50, Sunday 11.00-17.50 (last admission 17.30).
A limited number of free parking spaces is available for disabled visitors – call 020 7942 5888.
The Natural History Museum, Cromwell Road, London SW7 5BD



Darwin Centre

AT THE NATURAL HISTORY MUSEUM

Inspiring discovery of the natural world



Phase One Now Open

Darwin Centre

AT THE NATURAL HISTORY MUSEUM

NATURE'S TREASURES

Darwin Centre

AT THE NATURAL HISTORY MUSEUM

IN ASSOCIATION WITH

BBC wildlife MAGAZINE

TENTS

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THE DARWIN CENTRE

With the unveiling of this major new development at The Natural History Museum, an extraordinary treasure chest has been opened. **Phil Gates** went to take a look inside.

If you ask people how they remember their first visit to The Natural History Museum, probably as a child, most will mention one of the more spectacular specimens on display – most likely a dinosaur. Other memories triggered will include surprise and delight at the bewildering variety and beauty of animal specimens, and today's young visitors are bound to mention the modern interactive displays that excite the imagination, bringing preserved examples of the living world to life. Many visitors will also recall being awestruck by the sheer scale of the building and its contents.

Each year, two million visitors are unfailingly impressed with what the museum has to offer – but up until now, they have only seen one facet of the museum's activities and a small fraction of its resources. Few will realise that 350 scientific staff work at the museum, engaged in research projects that take them to every continent, or that there are millions more specimens in the research collections.

With the opening of Phase One of the Darwin Centre on 30 September 2002, that has all changed. The Natural History Museum has entered a new era, which will radically alter public perception of what a museum can be and bring people closer to the heart of its day-to-day work. Like the proverbial iceberg, most of the museum and its activities have been hidden from view. Now, with access to Phase One of the Darwin Centre, visitors have a chance to witness at first hand the fascinating research that goes on behind the scenes in one of the world's leading scientific institutions. They will also be able to see many more of the 70 million natural history specimens that have been accumulated during the museum's 250-year history.

Why a new centre?

The Darwin Centre has been designed with three aims in mind. The first is to provide the best-available facilities for maintaining and expanding the museum's collection of internationally important specimens, which are used by scientists around the world. Second, the Darwin Centre provides state-of-the-art scientific research facilities, which are essential in a century when understanding and conserving the natural world, much of which is under threat, will become even more important. And finally, it aims to create opportunities for better public understanding of nature by bringing people closer to the scientists' research and providing access to one of the finest collections of natural-history specimens in the world.

The treasures on show

The Darwin Centre was conceived in two phases. Phase One, open from 30 September 2002, is the new home for the museum's collection of 22 million zoological specimens preserved in alcohol. This collection, known as the Spirit Collection, includes specimens of fish, reptiles, amphibians, molluscs (snails and their relatives) and crustaceans (crabs and their relatives), which have been transferred from the old Spirit Building, dating from the 1930s. Until now, these specimens have not been seen by the public, though they are in constant use by the museum's scientists.

Phase Two, scheduled to open in 2007, will house the museum's botany and entomology departments, whose collections comprise 6 million plants and 28 million insect specimens. Buildings for both phases have been designed to provide the finest research facilities, which will allow the museum's scientists to make best use of its collections.

Meeting the scientists

The Darwin Centre redefines the popular concept of a museum. Besides providing unprecedented access to specimens, ➤

Richard Kalina

Phase One: As well as unprecedented access to historic collections (*top*), visitors can meet museum scientists and discuss the latest research (*inset*). The new building has a state-of-the-art south-facing solar wall (*right*), which tracks the movement of the sun and gives the building an 'intelligent skin.'

Graham Pellow

ıble to see scientists at work
·m about their research in the
: Live area. This resembles a
ı tv studio where, every day,
ıbout their work and discuss it
·'ia live, remote connections,
ɔ view other research areas
seum as well as watching and
ɦ scientists working at the
:rch station in Belize. For those
:e a presentation they missed, a
n of Darwin Centre Live
vailable on The Natural
m's website (see p35).
nakes use of the latest advances

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part of the Darwin Centre, but for the ultimate view of the inner sanctum of the museum, you will need to take a Darwin Centre Explore guided tour (see p35). Small groups of seven people will be taken behind the scenes to see the work of a scientific institution that for almost 250 years has been devoted to advancing the understanding of the natural world.

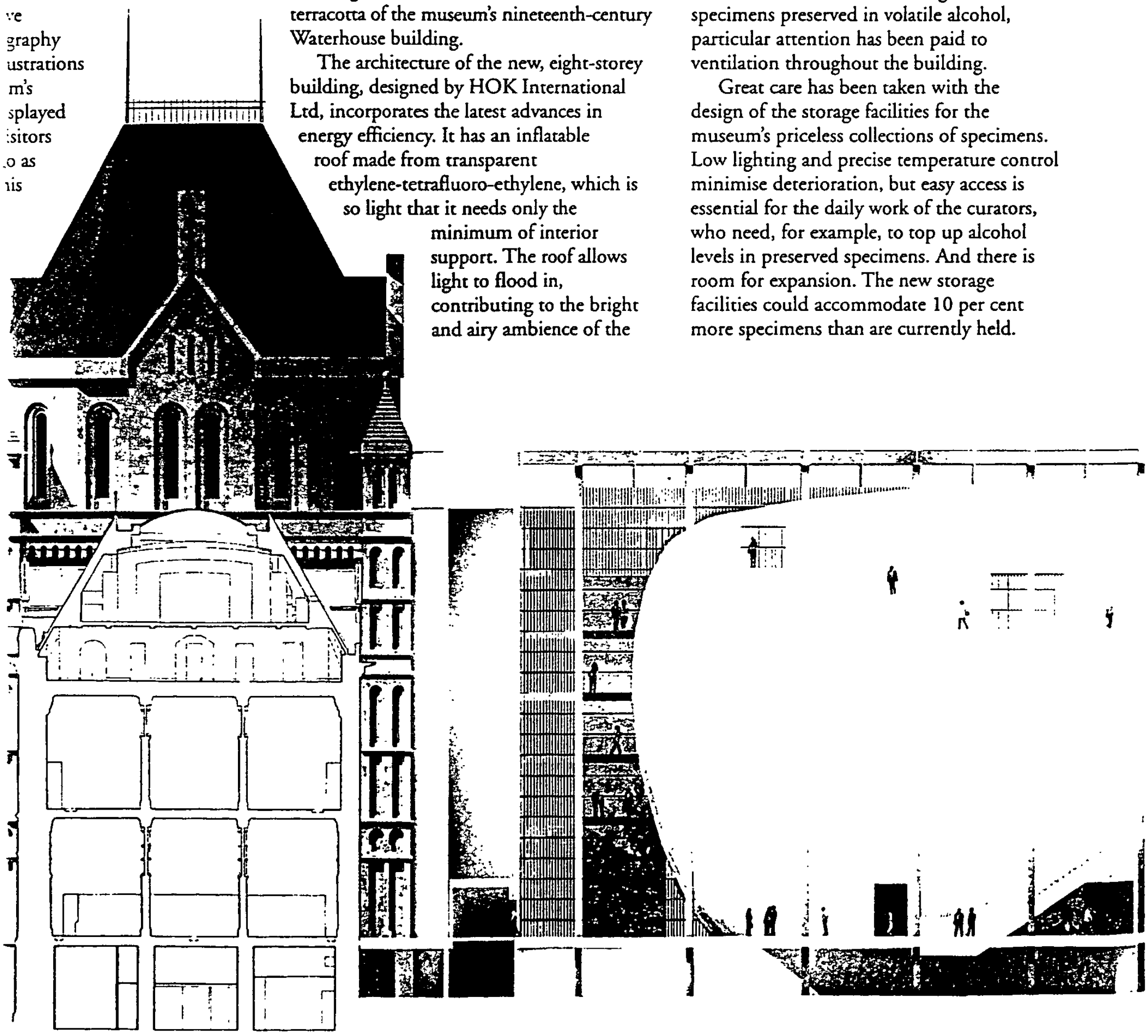
An eco-friendly design

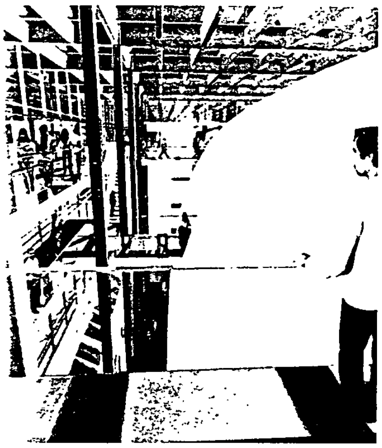
Phase One of the Darwin Centre is linked via a bridge from the mammals gallery in the main building. Using terracotta and steel framing in its design, the Phase One building echoes the sand- and blue-coloured terracotta of the museum's nineteenth-century Waterhouse building.

The architecture of the new, eight-storey building, designed by HOK International Ltd, incorporates the latest advances in energy efficiency. It has an inflatable roof made from transparent ethylene-tetrafluoro-ethylene, which is so light that it needs only the minimum of interior support. The roof allows light to flood in, contributing to the bright and airy ambience of the working spaces. Meanwhile, a south-facing solar wall supported by 104 organically styled brackets – like giant metal spiders – tracks the sun's movements, giving the building an 'intelligent skin,' which changes according to weather conditions and time of day. The solar wall is an energy-saving structure, reducing heat load in the summer and heat loss in the winter.

The interior design of the building allows for flexibility in the future. Laboratory furniture can be moved on castors to reconfigure the space when required. All the essential services for the building, such as water and electricity, are carried in a service spine that can be accessed and modified with minimum disruption. Since the scientists' research often involves working with specimens preserved in volatile alcohol, particular attention has been paid to ventilation throughout the building.

Great care has been taken with the design of the storage facilities for the museum's priceless collections of specimens. Low lighting and precise temperature control minimise deterioration, but easy access is essential for the daily work of the curators, who need, for example, to top up alcohol levels in preserved specimens. And there is room for expansion. The new storage facilities could accommodate 10 per cent more specimens than are currently held.





CF Møller Architects

ɔdern view. The development of Phase Two will open up even ɔre of the museum's collections to the public.

ne research laboratories are positioned on ɛ outside of the building, providing ıximum natural light. Each floor is devoted ı different specialisations. The tank room, ɔntaining the largest specimens preserved in ːcohol, is located in the basement. Just ɔove, on the first floor, scientists work on ːptiles. Those on the next two floors ·ecialise in reptiles and amphibians. ·icrobiologists, dealing with the smallest ·ing organisms, work on floor four, and specialists on invertebrates – animals without backbones – are located on floors five and six. Research on parasites is located at the top of the building, on floor seven. Each floor has extensive sectional libraries devoted to the relevant specialisations of the scientists working nearby.

From its basement to its inflatable roof, Phase One of the Darwin Centre has been designed as a state-of-the-art eco-friendly building, with efficient research facilities and the best available environment for the conservation of the museum's collections.

The future takes shape

Phase Two of the Darwin Centre is scheduled to open in 2007. It will be almost twice as big as Phase One and will house the museum's botanical and insect collections. The storage requirements for these dry specimens are quite different for those needed for specimens preserved in alcohol, and the new building should provide the best possible conditions.

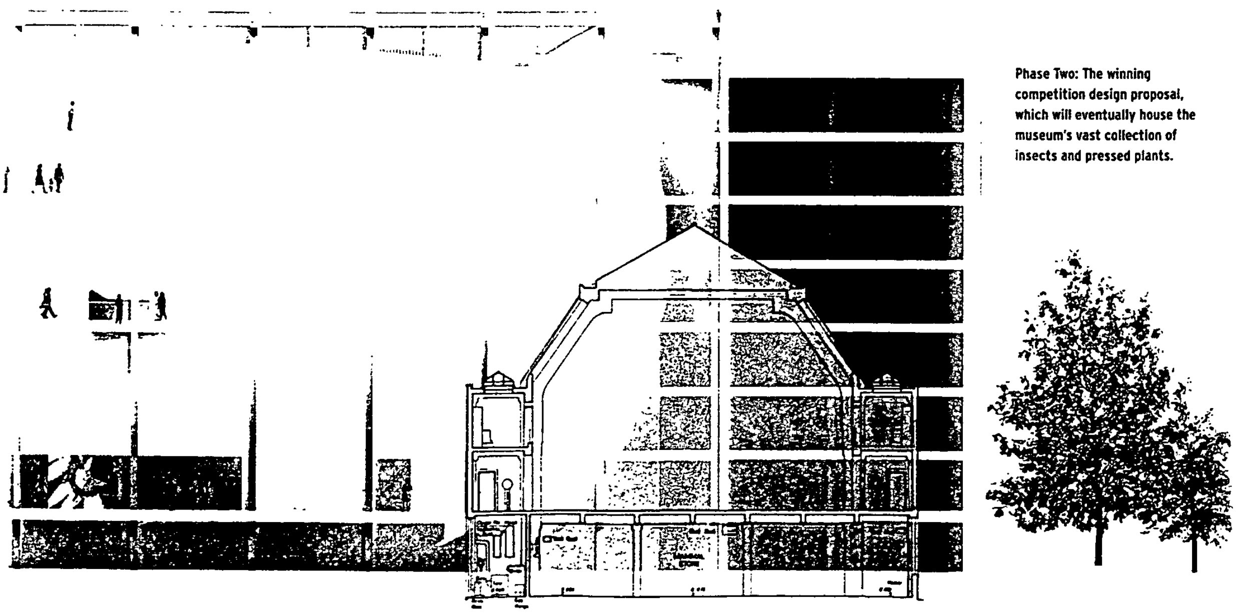
In 2002, Scandinavian architects CF Møller and Partners were appointed to design the new Phase Two building, after a competition that attracted entries from 59 teams. Møller and Partners already have experience of designing the extension to the National Museum of Art in Copenhagen and in the renovation of the Arhus Natural History Museum in Denmark. In their winning design, the insect and plant collections are housed in a curved 'cocoon,' visible through a transparent outer structure. The overall design concept, say leading architects Anna Maria Indrio and Tom Danielsen, will be "*to express in the language of architecture The Natural History Museum's vision of a unique meeting between the visiting public and the research scientists in the Darwin Centre.*"

MAKING IT HAPPEN

The completion of Phase Two

Now that an architectural design for Phase Two has been commissioned, The Natural History Museum urgently needs to raise funds so that the project can be completed. To find out how you can support the Darwin Centre and play a part in the £65-million fund-raising campaign, contact:

Erica Straus
Development Office
The Natural History Museum
Cromwell Road
South Kensington
London
SW7 5BD
☎ 020 7942 5890
fax: 020 7942 5291
e-mail: e.straus@nhm.ac.uk



CF Møller Architects

Phase Two: The winning competition design proposal, which will eventually house the museum's vast collection of insects and pressed plants.

WHY NAMES AND RELATIONSHIPS MATTER

With the advent of DNA analysis and a revolution in information technology, taxonomy and systematics have become fast-moving sciences with wide-reaching applications.

a name?

ıdispensable. Without it, the
ẏ of the living world would
·. Taxonomy creates names
tood and used by every
ıturalist throughout the
:r their nationality. It
.sic identification and
n for the library of life.
a set of taxonomists'
ranged in the form of an
:ey, scientists can name the
d in the field. Armed with a
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. a scientist can go to a
: in The Natural History
:nd a specimen.
ılways the case. Natural
ed early on that common
ı local dialects, had serious
e bluebell *Hyacinthoides*
:nglish woodlands is quite
the plant that the Scots refer
name but which the English
:ampanula rotundifolia.
·um maculatum has acquired
local and regional names
: United Kingdom. Common
ırful and culturally
ıre not much use for
ıunication. Turning to Latin
niversal languages of the
was the only answer.

One early attempt at scientific precision can be seen on Sir Hans Sloane's herbarium sheets in the museum. His plants are described in extended Latin sentences, which highlight the plants' key identification features. Sloane described the tropical plant that is now commonly known as frangipani as *Nerium arboreum, folio maximo obtussiore, flore incarnatus* which is a reasonable description of the plant's stature (a tree, *arboreum*), leaf shape (blunt, *obtussiore*) and flower colour (flesh pink, *incarnatus*) but is something of a mouthful for everyday conversational use. Worse still, different naturalists tended to concoct their own descriptions for the same species.

Cometh, the hour, cometh the man. Just as rapidly growing collections of natural-history specimens teetered on the verge of nomenclatural chaos, the Swedish botanist Carl von Linné (better known as Linnaeus) applied a stroke of editorial genius and cut down those long descriptive sentences to just two words. The first was the genus and the second, which was always in some way descriptive, was the species. He published his new rules for taxonomy in his *Systema Naturae* in 1735 and his classification of plants in 1753 in *Species Plantarum.*

Taxonomy's troubles were not completely solved, because numerous organisms have been named more than once. This is a problem that bedevils the study of biodiversity today. Some observers have calculated that 40 per cent of all known beetles have been named more than once. Deciding which should take historical precedence occupies a good deal of taxonomists' time. Mistakes can be made, too, giving different stages of a lifecycle or separate sexes of a single organism different scientific names. Even the great Linnaeus mistook male and female mallards as separate species of duck. But such difficulties can be solved. By 1776, English botanist William Withering, in an introduction to his survey of native British plants, could confidently proclaim: "*It is sufficient for the present purpose that the system of Linnaeus is now very universally adopted . . . it approaches near to perfection, that we may perhaps never expect to see any other improvements . . .*"

As far as naming species was concerned, Withering was quite right – we still use the Linnaean system today – but when it comes to deciphering the natural relationships between species, new methods have given us insights that Linnaeus would never have dreamed of.

Building connections

Linnaeus based his classification of plants into groups on the basis of the number and arrangement of the male and female reproductive organs, the stamens and pistils. This was a convenient way to write a key that allows quick and easy identification in the field, and is still used. If Linnaeus picked up a modern identification key to plant species, it would seem very familiar to him. But it's hardly surprising that such an arbitrary system tells us little about real evolutionary relationships between organisms, which became an increasingly important problem after the publication of Darwin's *Origin of Species* in 1859. Biologists who wanted to reconstruct evolutionary trees would be seriously misled if they relied on just one or a few obvious characteristics of an organism.

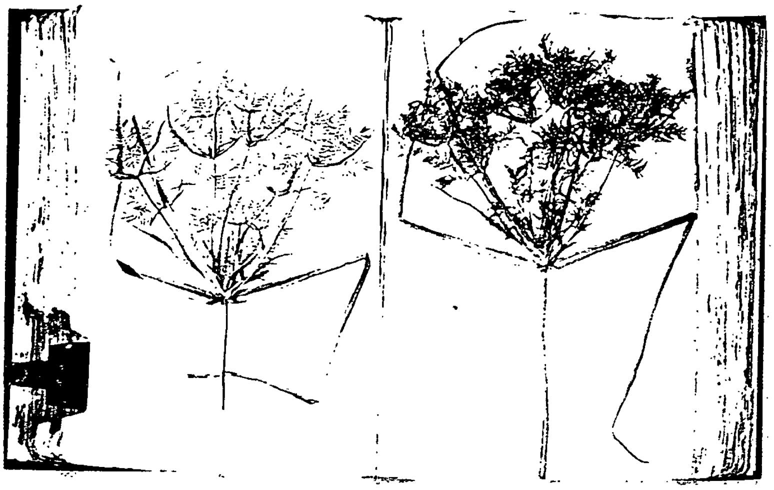
John Vaughan Thomas's discovery that barnacles were more related to shrimps >

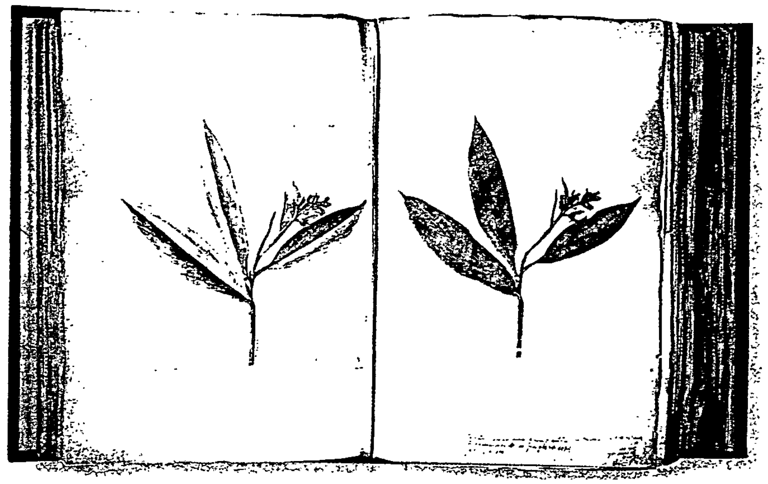
:bee bat *Craseonycteris thonglongyai*

es are much more than just labels for
;anisms – they often describe some of its key
me aspect of its discovery. The specific name
: – the smallest known mammal – honours its
bat researcher Kitti Thonglongya, who sadly
e full significance of the discovery was realised.
:ies was described by Natural History Museum
hn Edwards Hill, it was classified not only as a
ut also in a new genus belonging to an entirely
oats (see box, p11).

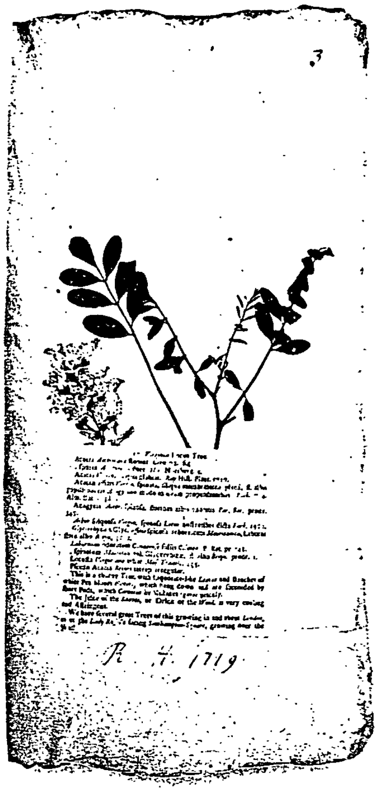
Maurice Tibbles/Oxford Scientific Films

:allest known mammal was named after its discoverer.

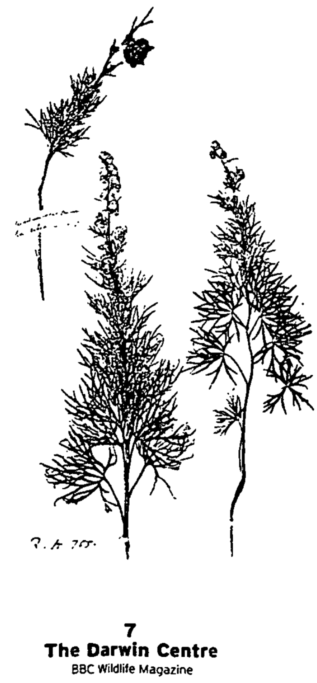




Middle left: Sir Hans Sloane described this wild ginger specimen as *Zingiber sylvestre minus, fructu e caudium summitate exeunte*. In modern-day Linnaean taxonomic parlance, it is known as *Renealmia antillarum* – an altogether more manageable name. Members of the ginger family are an important source of flavourings, but this species has a reputation as a tropical weed.



Above: The Virginia locust tree, from Sir Hans Sloane's *Hortus Siccus*. Sloane acquired his collection via a web of contacts, who can be traced through his correspondence. Specimens of the Virginia locust tree were sent to London apothecary James Petiver by North Carolina botanist John Lawson in the early eighteenth century. When Petiver died in 1718 Sloane bought his collection.



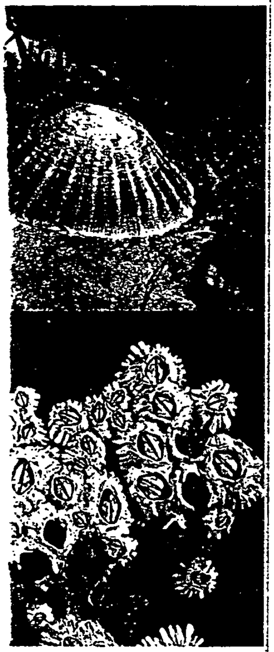
Top left: Sloane called this specimen *Cyperus longus odoratus*. Unfortunately, the contemporary botanist John Ray used exactly the same phrase to describe another species, galingale. Linnaeus came to the rescue. Sloane's species became *Cyperus odoratus*, while galingale acquired the name *Cyperus longus*. Galingale root has a long history of use as a food flavouring. The genus *Cyperus* includes several economically important plants, such as *C. papyrus*, used by the ancient Egyptians for making paper.

Left: Monk's-hood *Aconitum salutiferum*. Sloane took every opportunity to acquire new and interesting specimens. He picked this monk's-hood plant in the garden at Hampton Court, where it may have been grown for its medical properties. As a physician, he might have used it as a heart stimulant for his patients. Some monk's-hood species are lethally poisonous and were once used for executing criminals.

Far left: Root extracts of rhubarb *Rheum* spp. were used as a purgative in herbal medicine in China long before its culinary virtues were exploited and may well have been used by Sloane himself. The species on this herbarium sheet comes from eastern China and may be a species of dock (*Rumex*), a close relative of true rhubarb.

ES AND LIMPETS

›f mistaken identity



Ͻne is related to snails, the other to ɜrnal appearances give little away.

Ͻs, barnacles – those tiny
ɜls that survive on exposed
cementing themselves to
:lassified alongside limpets
ɔf the mollusc phylum, which
slugs and snails (see box, p11).
ᵋ a reasonable assumption;
ɟ limpets have a similar shape
·ɔy-side in the same exposed
. in 1830, Irish surgeon and
.ralist John Vaughan Thomas
planktonic animals which
:he larval stages of
– the family that includes the
:s and lobsters – and watched
:hemselves to hard surfaces
ᒥ into barnacles. The news
:s were shrimps that glued
ɔ rocks, secreted a shell and
ɟs' for filter-feeding was
ncredulity at first. But it
ɟ the dangers of classifying
.rely on the basis of the
ɜarance of one stage in the
ᵋ was a case of convergent
·ere two distantly related
impets and barnacles – had
ɜr external adaptations for
·ficult circumstances, under
nding by waves.

than snails (see box, left) led to a complete anatomical reappraisal of barnacles. Charles Darwin devoted a large part of his career to collecting and dissecting them, and his monograph on the subject published in 1854 remains an important source of reference today.

The key to understanding how organisms are related often comes from studying a wide range of different characteristics, sometimes at a variety of stages in an organism's lifecycle. In 1966, a German systematist called Willi Hennig developed a method for identifying the most reliable forms of taxonomic information and a system for using it to construct 'evolutionary trees.' Hennig's method, called cladistics, grouped organisms according to how recently they shared a common ancestor.

Traditional systems for classifying species have depended mainly on comparing their morphology – their appearance and internal structure – such as their skeletons or internal organs. It's a method that works well in many situations and is still the bedrock on which all descriptions of new species are based. But it has many limitations. In some organisms – particularly small ones such as bacteria, algae or even nematode worms – there are few obvious features that can be used to separate similar species. Sometimes, in the case of mosquitoes, for example, species are known to exist that look identical and can only be recognised as being separate species by the fact that they don't interbreed. And then there is the ever-present problem of convergent evolution, where organisms that look similar, and therefore might be supposed to be closely related, are really unrelated species that have evolved similarities, because they are adapted to the same kind of environmental pressures.

Decoding genes

Systematists were provided with a powerful new tool for solving many of these difficulties when the chemical structure of the DNA molecule was discovered in the middle of the last century.

Genes, composed of DNA molecules, are the molecular blueprint for all the features – visible and invisible – of all living organisms except certain viruses. These organisms evolve because their genes mutate during

Frozen assets. The application of modern DNA technology to systematic studies is already contributing valuable new information for conservation, agriculture and human health.

reproduction, through spontaneous changes in the order of chemical bases in the genes' DNA molecules. The variation in characteristics that this produces in a mutant individual is sometimes beneficial, making the individual fitter so that it can successfully compete with its non-mutant peers and produce more offspring like itself. Generation by generation, the numbers of the successful mutants increase, favoured by this process of natural selection, and the species evolves.

As the sequence of chemical bases that make up the genetic code in the DNA molecule changes over time, it is possible to compare the sequences in the same gene in two different species and tell how closely related they are – the longer ago they separated into two species, the more differences there will be in the sequence of bases in their genes.

By comparing DNA sequences from collections of species, it's possible to construct reliable family trees, grouping living organisms according to their common ancestry. Species from a single common ancestor are the ultimate 'twigs' of the tree, linked via 'branches' to more distant ancestors in the 'trunk.' And now that ancient DNA can be extracted from remains of long-extinct animals – from skins or teeth of animals preserved in the museum collections, for example – even extinct species can be included in these evolutionary trees.

Sometimes it is also possible to put a :imescale on evolutionary change. DNA .nolecules tend to mutate at a fairly constant rate within closely related groups of species – within the whales, for example – ınd so the mutating DNA acts as a ticking 'molecular clock', from which the timescale for evolutionary change can be calculated.

The evolutionary history of species is quite literally written in their genes. Physical appearances can be deceptive. The Old World vultures of Asia and Africa look very similar to the New World vultures of North America, but that's just an :volutionary coincidence; DNA analysis hows that this is yet another case of convergent evolution, brought about by .daptations to similar lifestyles. North American vultures have a much closer volutionary relationship with storks than vith African vultures.

The Natural History Museum has the neans, in its Molecular Systematics Laboratory, to decode these ancient pedigrees. And this kind of work is already achieving much more than merely satisfying scientists' ntellectual curiosity. Unravelling the volutionary relationships within the bewildering diversity of beetles and nderstanding how unique races of aphid pecies evolve on different host plants has provided valuable insights into rapid volutionary change in important agricultural ests. These molecular systematic techniques ave been used by the museum in research rogrammes designed to help improve >

Wendy Shattil and Bob Rozinski/Oxford Scientific Films

ook-alikes. Despite appearances, the North American turkey ılture (*above*) is more closely related to storks than to Asian or frican vultures such as the Cape vulture (*right*).

A 'living fossil' from New Zealand

For many years after its discovery, it was thought that just one species of tuatara *Sphenodon punctatus* existed, but more recent research, using DNA sequence analysis, has revealed a second distinct species, *S. guentheri*, living as an isolated population on New Zealand's North Brother Island.

Close comparisons using new technologies can reveal the existence of new species. For this reason, the Darwin Centre now routinely preserves frozen tissue samples in its collections. These allow for easy extraction of DNA samples, which can be used for species comparisons.

The tuatara lizard is particularly important because it is a *'living fossil'* – the last living descendant of an order of reptiles called the Rhyncocephalia, which flourished more than 200 million years ago. The discovery of *S. guentheri* has given conservationists an extra species to worry about, since the lizard needs constant protection from the introduction of domesticated animals and rats, which have led to the demise of many rare and isolated island species elsewhere.

On the rocks? The tuatara is one of several recent examples where DNA analysis has demonstrated the existence of more species than was previously thought.

Winfried Wisniewski/FLPA

)NOMY IN EVERYDAY LIFE

and systematics play a much more important role in our ives than most of us realise.

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:ural industry, : gardening rden centres, niversal system es so that they ccurate advice heir products. ers try to make ; more wildlife rowing native an obtain free posing the best ow in ea at The ry Museum a website, s the Postcode ase: **.uk/science/ index.htm**

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npted to rooms from the nge from the rieties in your arket? For you need to taxonomic a good field n by expert Mistaking a a field ould be fatal.

Good taste? The morel *Morchella esculenta* is a spring fungus prized by chefs though not to be confused with the similar – but poisonous – false morel *Gyromitra esculenta*.

Enjoying a country walk

If you enjoy walking in the countryside or along the coast, you'll probably want to identify some of the wildlife you see. Good field guides to many groups, such as birds and wildflowers, are now commonly available. These are the result of 250 years of taxonomic research, dating back to Linnaeus. You can access some computer-based identification keys and guides on the museum's website, for example:

For lichens that grow on twigs:
http://internt.nhm.ac.uk/cgi-bin/botany/lichen/
Sea urchins:
www.nhm.ac.uk/palaeontology/echinoids/keys/key1.htm
Polychaetes (marine worms):
www.nhm.ac.uk/zoology/taxinf/index2.html
Invertebrates that you are likely to find in the garden:
http://flood.nhm.ac.uk/eb//invertkey.html
Whales and other marine mammals:
www.nhm.ac.uk/zoology/stranding/idguide.html

Guarding against disease

With so many of us taking holidays in tropical locations, it's vital to protect ourselves against tropical parasites, and decades of research into their lifecycles have provided essential information for developing protective drugs. If you are unlucky enough to be infected with a tropical parasite, your doctor will depend on taxonomic advice for effective treatment.

Enforcing quarantine

International travel enables disease organisms that infect plants and animals to move around the world faster and more easily than ever before. Import and quarantine regulations depend on accurate taxonomy to ensure that these organisms and the plants and animals which harbour them are not brought into the country.

Enforcing international law

While on holiday abroad, you may well find souvenirs on sale made from parts of endangered animals protected under the Convention for International Trade in Endangered Species (CITES). Importing these souvenirs is illegal, and taxonomists have methods for identifying the source of products such as animal skins from the surface pattern of a single hair. Find out about CITES listings at: **www.cites.org**

Food contamination

Unusual contaminants, ranging from insects to parts of animal skeletons, can sometimes find their way into tinned or frozen foods. These contaminants can be identified by skilled taxonomists, who can often help to locate the source of contamination.

Criminal forensics

Many crimes are solved on the basis of forensic evidence, which often needs the skills of a taxonomist. Forged paintings can be detected by identifying the source of fibres in the canvas, alibis can be falsified on the basis of pollen samples on clothing, and wood splinters from bomb blasts can identify the location of explosive devices.

human health, including studies on malarial mosquitoes and *Plasmodium falciparum*, the organism that causes malaria. Similarly, research on sandflies, which transmit the disease Leishmania, and on blackflies, which spread the parasites that cause river blindness, are helping to combat these diseases.

An evolving web

Systematics is a fast-moving science, and new information leads to a constant questioning of existing ideas about species relationships. A recent re-ordering of flowering-plant families, based on data from DNA, has led to a redrawing of their evolutionary tree. The new juxtapositions of botanical families give scientists who search for useful chemical compounds in plants – for use as drugs, for example – powerful clues as to where they should look. If they find useful drugs in one plant family, investigating its closest relatives, which share a common ancestor, is likely to provide the best chance of finding similar useful compounds. Systematics can inject logic into what would otherwise be a random, needle-in-a-haystack search.

Even at the highest levels of taxonomic classification, new molecular studies have altered the way we think about the living world. In Sir Hans Sloane's day, a taxonomist's life was relatively simple. Living things belonged to one of two kingdoms, plants or animals. By the 1950s five kingdoms were recognised: plants, animals, fungi, bacteria and a kingdom called protoctists, which included algae and organisms such as amoeba. Current opinion, based on analysis of DNA sequences, suggests that this is too simplistic. There should be a higher level of classification of life – into three domains – and there may be as many as 30 distinct groups worthy of the term 'kingdom' (see *BBC Wildlife*, August 2002).

At the practical level, taxonomy and systematics are the basic tools for classifying and identifying the natural world. And among the species that sit at the end of the twigs of that metaphorical evolutionary tree, molecular analysis is revealing new species that until now have been overlooked. Over the past few years, for example, DNA sequences have

Getty Images

:ess the relatedness between organisms, their DNA e sequence of chemical bases – adenine, thymine, – which make up the genetic code can be compared.

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g g c a t g t

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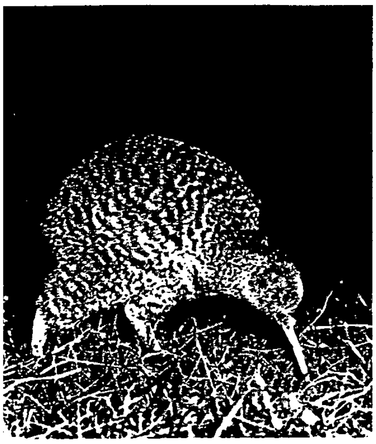


·ight-bird. The great spotted kiwi *Apteryx haastii* (*above*) was one ·f three kiwi species, along with little spotted and brown kiwi, ·ntil DNA studies revealed a small population of browns so ·ifferent from the others that they warranted new species status.

·evealed that there are four kiwi species in ·ew Zealand, not three as previously believed, ·nd that there are two distinct species of ·ipistrelle bat in Britain. Such discoveries ·ring home the value of keeping frozen tissue ·amples of species for DNA analysis.

·he challenge ahead

·stimates of the total number of species ·ange between 3 and 100 million, yet fewer ·han 2 million species have been found, ·escribed and classified. This indicates the ·cale of the task facing taxonomists.

Taxonomy and systematics are the ·oundation of all biology and underpin all ·fforts to conserve biodiversity. Without a ·able, reliable system for classifying the living ·orld which is universally understood and ·pplied, it would be impossible to carry out ·ational scientific research that is useful to ·veryone. Without a system for identifying, ·ataloguing and understanding relationships ·etween species in the field, our ability to set ·riorities for species-conservation work and ·o measure its success is diminished. And yet ·axonomy and systematics are two of the most ·nderfunded sciences throughout the world.

By becoming a centre of excellence in ·hese disciplines and by integrating collecting, research and science communication in the Darwin Centre, The Natural History Museum aims to raise awareness of the value of taxonomic and systematic research. Training the next generation of taxonomists is particularly important, especially as many of the scientists currently working in this area approach retirement. Young people who are inspired to study the natural world, perhaps through visiting the museum, often go on to study biology at university. From there, they can progress to the MSc degree in taxonomy, run jointly between the museum and Imperial College, and then go on to study at PhD level alongside museum scientists. Through collaborative international research and training prgrammes, museum staff also help train taxonomists worldwide, especially in developing countries, where biodiversity is greatest and the need to classify it is most pressing.

New-age technology

The old image of taxonomists equipped with butterfly nets and plant presses is misleading, though this kind of equipment still has an important role in fieldwork. Modern taxonomy uses state-of-the-art laboratory equipment – electron microscopes, digital imaging and automatic DNA sequencers. Today's taxonomists need to combine the instincts of a naturalist with the skills of a molecular biologist and the easy familiarity with digital technology that would have been unimaginable just a couple of decades ago.

Computers play a vital part in storing taxonomic information in a rapidly retrievable form. This can range from species lists and simple identification keys to global biodiversity maps and massive databases of DNA sequences. The new science, known as informatics, for dealing with this information explosion is becoming an increasingly important aspect of the museum's work. The internet will also be a vital tool through which to disseminate research results and supply information about museum resources to scientists, conservationists and interested members of the public around the world.

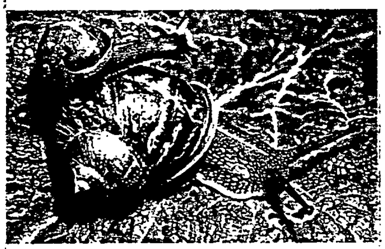
A LIVING SYSTEM FOR LIFE

How the living world is sorted

Taxonomy is the science of discovering, describing, classifying and naming species in the living world and arranging them according to similarities and differences. Taxonomists, the scientists who do this work, aim to refine the classifications that they use and to develop better systems for identifying species.

Systematics is an extension of taxonomic study that works towards grouping species according to their evolutionary ancestry, rather than merely on the basis of their similarities, which can be misleading.

Classification is the way in which organisms are sorted into a series of categories that become increasingly exclusive, providing a unique identity for each species. Below, for example, is the systematic classification for a garden snail.



Ken Preston-Mafham/Premaphotos Wildlife

Kingdom: *Animalia* (animals)

Phylum: *Mollusca* (mollusca is the Latin word for 'soft' – all molluscs have soft bodies, which many protect by secreting hard shells)

Class: *Gastropoda* (a Latin word meaning 'stomach-foot' – snails have a mouth on the underside of their creeping foot leading to their stomach)

Order: *Pulmonata* (meaning that they have a lung – land snails breath air, unlike their aquatic cousins, which use gills)

Family: *Helicidae* (a family with large shells that are coiled, or helical)

Genus: *Helix* (which also refers to the coiled nature of the shell)

Species: *aspersa* (which means 'rough' and refers to the slightly wrinkly surface of the shell)

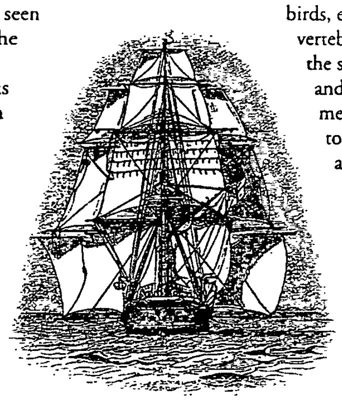
ɔne man's obsession more than 300 years ago grew a priceless collection. For the first time in the ɜum's history, visitors will now have behind-the-scenes access to 22 million of these specimens.

began

ɔne man's magnificent collecting, that most basic of ·s, which seeks to impose ˙order on groups of objects, in :wildering variety of life that :ural world.

: (1660-1753), a wealthy ·illar of medical and scientific ·me of the formative years of hysician in Jamaica, where he collection of plants – then a of medicines used in his 689, he boarded ship to th large collections of ɔecimens of birds, fishes and ɔgether with a live iguana, a two-metre-long snake, which :ation among the crew and the voyage. Among his Sloane brought back the first specimens of cocoa to be seen in England, from which he later invented milk chocolate, prescribing this to patients suffering from consumption.

Sloane rose to succeed Sir Isaac Newton as President of the Royal Society, and for the rest of his long life continued to collect natural history artifacts on a grand scale. 'Cabinets of curiosities' had become fashionable in eighteenth-century society, and Sloane's collection became one of the wonders of the age. It included pressed plants in bound volumes of herbarium sheets (see p7), 12,500 glazed boxes containing 'vegetable substances,' rocks, minerals, 6,000 shells. 9,000 invertebrates, 1,500 fish, 1,200 birds, eggs and nests and 3,000 vertebrate specimens, including the skeleton of a young elephant and a whale skull more than five metres long. Sloane allowed it to be purchased for the nation at a very low price for "the inspection of the learned and the benefit of the public," and an Act of Parliament on 7 June 1753 established the British Museum to accommodate this national treasure, financing the purchase of Montagu House in Bloomsbury, where the collection was to be kept, with proceeds from a national lottery.



Wind of change. Five years aboard *HMS Beagle* led to Darwin's radical ideas about evolution.

The British Museum became the nation's centre for scientific study of natural history specimens collected on many subsequent expeditions. It provided a home for the specimens, paintings and written records collected by naturalist Joseph Banks (1743-1820), who accompanied Captain Cook on his voyage around the world on *HMS Endeavour* between 1768 and1771. Notably, Banks' collections were arranged according to the new-fangled Linnaean system of classification, rather than the methods used by Sloane. The Linnaean system, designed to classify organisms according to observable features that reflected natural relationships, established the science of systematics, which underpins all modern biology and is still a major theme of scientific research in The Natural History Museum today. The collections from Cook's voyages include a drawing of a kangaroo made in 1770 by Sydney Parkinson, artist on *HMS Endeavour*, introducing Europeans to this marsupial – "as large as a greyhound, of a mouse colour and very swift."

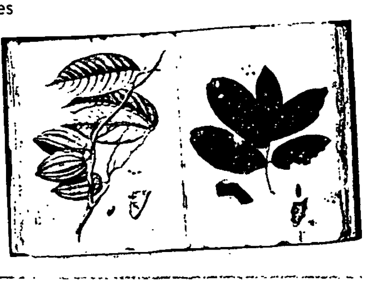
Charles Darwin (1809-1882), one of the most famous of all scientists, was engaged as a naturalist on *HMS Beagle* during a voyage

arium sheets to milk chocolate

· sheet from Sir Hans Sloane's collection, with its pressed specimen of cocoa :ao leaves, is among The Natural History Museum's most treasured possessions. · drink made from cocoa while living in Jamaica, and was not impressed. *ı hard of digestion,"* was his verdict. When he returned to England, he ɔy mixing cocoa seeds with milk to produce the first milk chocolate. Derivatives of ɜcipe, obtained by Cadbury in the nineteenth century, are still on sale today.

·barium contains 120,000 plant specimens, arranged in 338 bound volumes of which he labelled meticulously, greatly enhancing their scientific value, but they ·ether haphazardly. Linnaeus, though impressed with the size of Sloane's cribed it as being *"in complete disorder."* The great Swedish ɔunded the system of naming species ı taxonomy, favoured a more : of mounting pressed plants on und sheets so that they could be he light of advances in scientific ·e system that is still used today.

:tory Museum holds a collection ·essed plant specimens. The .omology departments will be ıase Two of the Darwin Centre.

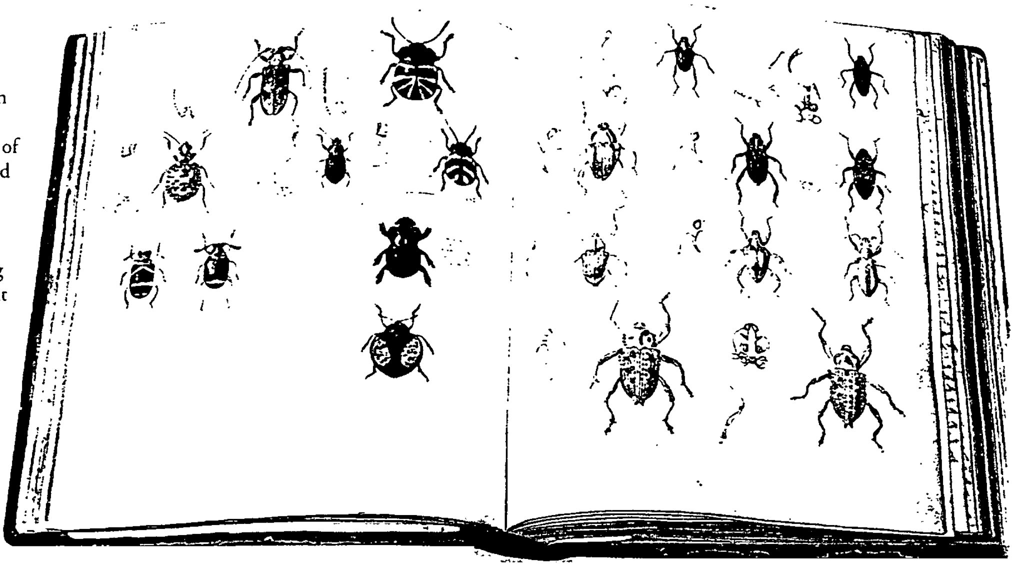


e was the first to bring cocoa to England, he invented milk chocolate.

› map the South American ›oast in 1831. The ship's ›e-year circumnavigation of ›e globe provided time and ›pportunity for Darwin to ›ollect and reflect on the ›milarities and differences ›etween species, generating ›e spark of inspiration that ›d to his theory of ›olution by natural ›lection. It is hard to ›nderestimate the ›portance of Darwin's ›ork, neatly summed up ›· modern-day geneticist ›heodosius Dobzhansky, ›ho observed that ›othing in biology ›akes sense, except in ›e light of evolution." Darwin, like every ›rious naturalist before or since, collected in ›der to make comparisons and classify ›ganisms, which led to his insights on the ›igins of the vast variety of life. His famous ›nches, collected in the Galapagos Islands in ›335 and credited with an inspirational role › the development of his theory of ›olution, are housed in The Natural History ›useum's collections, as are his domestic ›geons, chickens and ducks. He used the ›tter to demonstrate the store of hidden ›riability within species, which could be ›vealed by selective breeding, proving that ›ecies are not forever fixed or immutable in ›eir characteristics.

The collections grew rapidly during ›e nineteenth century, a great age of ›ientific exploration. Henry Walter Bates ›825-1892) lived and worked in Amazonia ›om 1848 to 1859, collecting 14,000 ›sects, 8,000 of which were new to science. ›e illustrated many with exquisite coloured ›awings (*above*) accompanied by detailed ›ld observations. Bates' specimens are ›otable for including multiple collections of ›rticular species, highlighting the variability ›etween individuals within a species. ›onserving this variation, both as an economic resource and as an essential prerequisite for the long-term survival of species, is a major goal in modern biology. Exploiting such variation forms the basis of all modern plant and animal breeding, while the apparently endless variety within pest species is a perpetual source of difficulty in defending crops, domestic animals and humanity against pests and diseases.

Exploration in the nineteenth century revealed a seemingly inexhaustible supply of surprises. The voyage of *HMS Challenger* between 1872 and 1876 (a state-funded research project, paid for by the British Government) plumbed the depths of oceans. These were previously thought to be largely empty, but an astonishing array of organisms were trawled and dredged from the deep, opening up a new frontier in natural history. Even today, assumptions that parts of the ocean might be lifeless continue to be confounded by new discoveries. In the late-twentieth-century, for example, new life forms were found in the boiling waters around deep sea hydrothermal vents and life was discovered on the abyssal plains at the bottom of the oceans, some parts of which are less well explored than the surface of the moon.



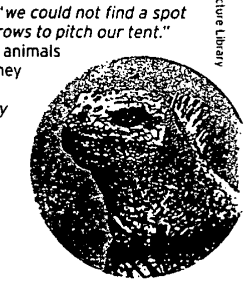
Amazon mix. Bates was fascinated with variability – both within and between species – and illustrated many of his finds.

The Galapagos iguanas

During *HMS Beagle*'s visit to the Galapagos Islands in 1835, Captain Fitzroy collected two different species of iguana, which are now among The Natural History Museum's stuffed collections.

Darwin described the marine iguana *Ambylrhynchus cristatus* (*below*) as "*a hideous-looking creature... stupid and sluggish in its movements... In the water this lizard swims with perfect ease and quickness, by a serpentine movement of its body... I opened the stomachs of several and found them largely distended with minced sea-weed.*"

He was amazed by the numbers of land iguanas *Conolophus subcristatus* on James Island, noting that "*we could not find a spot free from their burrows to pitch our tent.*" Like so many other animals in the Galapagos, they were "*not at all timorous... and try to look very fierce: but in reality they are not at all so.*"



Pete Oxford/Nature Picture Library

"It seems as if nature had taken precautions that her choicest treasures should not be made too common and thus undervalued."

Alfred Russel Wallace, lamenting the difficulty of collecting birds of paradise in Sarawak, in his book *The Malay Archipelago* (1869)

; of the deep

ırgest collections in The Natural
ɜum came from the world's first
ıic expedition. Between 1872 and
:hallenger sailed the oceans,
depths that had previously been
ɐ virtually lifeless. The
ɔst the treasury £200,000 – a
hat time – but the results more
he cost and effort. The
scientists returned with 715 new
:,717 new species of ocean life
pent the next 19 years
ɐport that ran to 29,552 pages.
er expedition opened up a new
entific exploration of Earth's
evealing animals that were a
rce of surprise and delight.
naturalist on the voyage,
ɐ rare capture of a nautilus:

off Matuku Island, in 320
ɐ coral bottom . . . a few shells
: up . . . and with these a living
*:he pearly nautilus (*Nautilus
ɿis was the only specimen
ng the voyage of the
' this animal, so rarely seen in
dition by any naturalist.

·i was very lively, though
so lively as it would have been
obtained from less depth, the
ɜe of pressure having, no doubt,
ɜarranged its economy . . . It,
:m round and round in a shallow
:the animal was frightened or
ɜde a sort of dash, by squirting
' from its siphon . . ."

The pearly or chambered nautilus
'us is a cephalopod (a name which
ıead-foot') along with the squids and
:ilus is a 'living fossil', little altered from
:tors that swam in Jurassic oceans 200
). It lives at great depth in the Pacific
g its position in the water using
ers in its shell and swimming by jet
'ting water out of a siphon.

The museum's collections grew rapidly in the early days through the efforts of many collectors. The pace of scientific advances and public fascination with the exotic and unknown served as a stimulus for the scientific profession to learn more about the world's flora and fauna, and skilled collectors supplied a steady stream of specimens. One such figure was Alfred Russel Wallace (1823-1913), a professional collector, contemporary of Darwin and co-expounder of the theory of evolution by natural selection. Wallace travelled the Malay region between 1854 and 1862, collecting more than 125,000 specimens, including many butterflies that now reside in the museum.

Sloane's collections, and all the others that joined it, remained at the British Museum in Bloomsbury until 1881, when they had grown to such proportions that new accommodation was long overdue. They were moved to the present museum in South Kensington (built specifically for the purpose), and, apart from a short sojourn in caves in Godstone Quarry to escape the Blitz in the Second World War, they have remained there ever since. The collections steadily increased in size and importance until yet another move was needed – in the new millennium. This time, the journey was only a matter of metres, from the old Spirit Building, which held millions of specimens preserved in alcohol, to the first phase of the Darwin Centre.

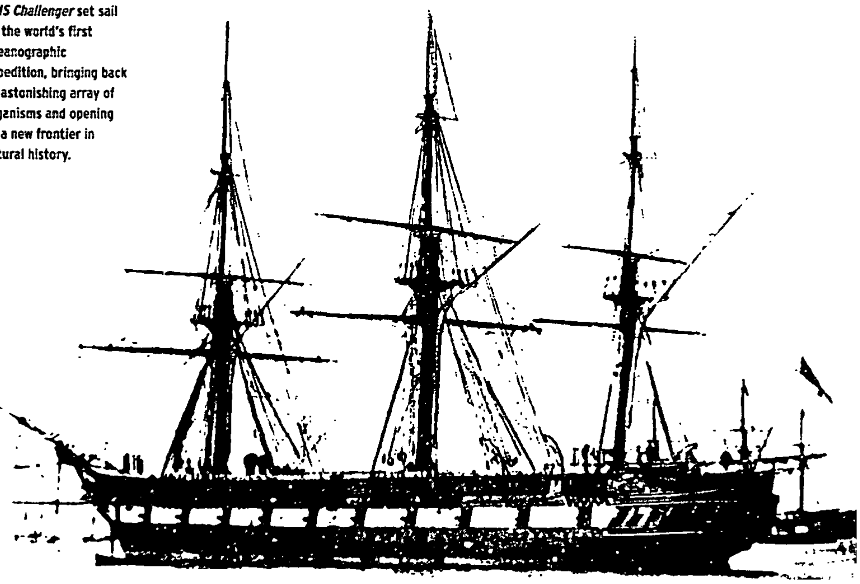
Ethics: then and now

Many famous and important specimens originated from organised expeditions, and the role of professional natural historians and scientists grew, but at the same time, amateur collectors scattered throughout the vast British Empire continued to make important contributions. In 1902, in his introduction to the *Handbook of Instructions to Collectors*, Director of the British Museum (Natural History) E Ray Lankester noted:

"*In past years the Museum collections have been greatly augmented and enriched by the donation of valuable series of specimens obtained by travellers and others whose vocations have necessitated their residence abroad in all parts of the world. It often happens that military and naval officers, explorers, missionaries, and others have leisure time which they would be willing to devote to collecting natural history objects . . .*"

The handbook consisted of a guide to collecting and preserving specimens, together with a 'wants' list of species that the museum wished to acquire, should the creatures happen to wander through a hunter's rifle sights or flit within range of a butterfly net. The list included the Javan rhinoceros and a number of other rarities – today it resembles a roll call for doomed species. Even then, at

Ship shape. In 1872, *HMS Challenger* set sail on the world's first oceanographic expedition, bringing back an astonishing array of organisms and opening up a new frontier in natural history.



:he beginning of the twentieth century, there ·vas a grim acceptance that Earth's natural upplies of biodiversity were not nexhaustible and were already in danger. As _ankester laconically remarked:

"*. . . in view of the approaching partial, if ıot complete, extermination of many species, it s of the highest importance that the Museum hould acquire a series of skins of all the larger pecies . . . as a study collection.*"

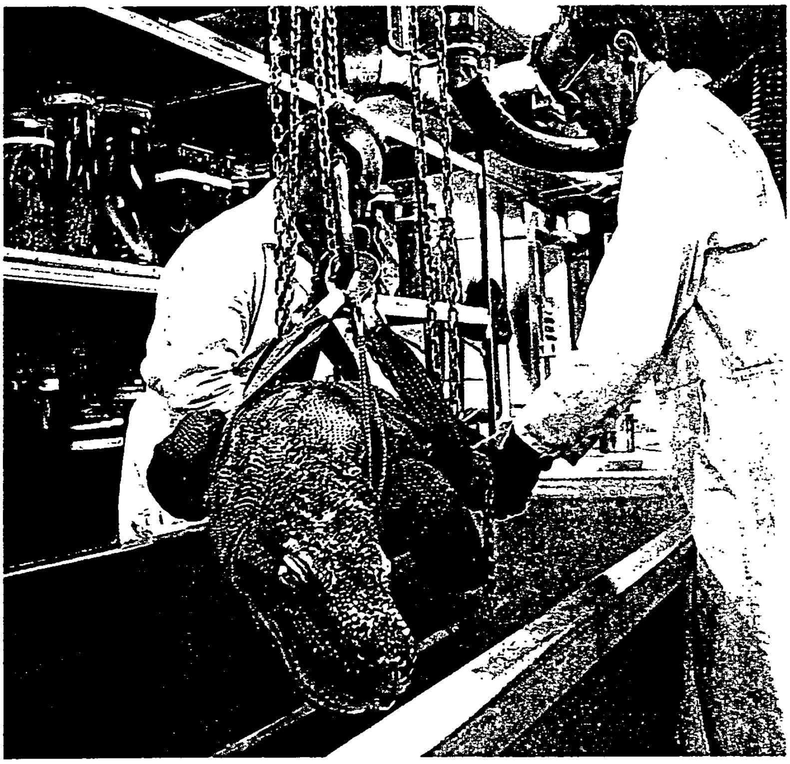
)ne salutary reminder of the tragedy of xtinction can be found in the mammal ollection. During the Challenger :xpedition, one of the ship's scientists, Dr)J Cunningham, collected specimens of the 'asmanian wolf, or thylacine. His .issections of the legs, together with the reserved internal organs of this unique ıarsupial wolf are now in The Natural ·listory Museum. Ten years after the end of ıe voyage, Tasmanian sheep farmers ersuaded the Australian government to pay bounty for every wolf killed, and the last onfirmed wild animal was shot in 1930. ·enjamin, the last captive Tasmanian wolf, 'ngered on in Hobart Zoo until 7 September 936, and there have been no authenticated 'ghtings of this species since.

Today, a century on from Lankester's ·arning, the ethics of collecting have moved n, driven by an enlightened approach to :udying the natural world and by the ıreat of imminent extinction of so many ɔecies. It is internationally accepted that a :ientific understanding of the natural 'orld is crucial to the future conservation f its biodiversity. The Natural History luseum's scientific research ensures that the ıillions of specimens which have been ɔllected in the past are used to the ıaximum benefit of those living species .ıat remain.

Preserving a Komodo dragon

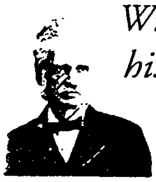
The only large animals which are now added to The Natural History Museum's collection are those that die accidentally, from natural causes in zoos or are confiscated from illegal collections. Sumba, the Komodo dragon *Varanus komodoensis*, preserved in a tank of alcohol in the tank room of the Darwin Centre, lived at London Zoo from June 1927 until October 1937.

Komodo dragons are the world's heaviest lizards, typically weighing about 70kg. They live on a few, small Indonesian islands, including Komodo. Though they are capable of a surprising turn of speed in short bursts, Komodo dragons prefer to ambush prey or feed on decaying carrion. They use their tails as well as their teeth in attacks, and though their bite may not be immediately fatal, their saliva is full of toxic bacteria, and so wounds quickly become infected.



Heavy lifting. Sumba reaches 2.3 metres from nose to tail, about a metre shorter than the largest known Komodo dragons.

Peter Durrant



'On stepping out of the bushes I met face to face a huge serpent coming down a 'lope, making the dry twigs crack and fly with his weight as he moved over them ... Wishing to take a note of his probable size and the colours and markings of his skin, I set off after him; but he increased his speed, and I was unable to get near enough for the purpose."

Henry Walter Bates, on collecting in Amazonia, in his book *The Naturalist on the River Amazons* (1863)

ıt songster

:cimen in the Darwin Centre spirit collection is a American amphibian called a greater siren *Siren* ·rived in the collection on 26 August 1768, sent by Garden of Charles Town (later Charleston), South !en was an English plantation owner, who cultivated :tive American plants. He sent preserved specimens starfish, molluscs and fungi to European :en via the London naturalist John Ellis, who also ren collected by Garden to Linnaeus, the famous omist. Garden was an acute observer, supplying :pecimens, their habits and habitats, which made ·ore scientifically valuable. "Head snake-like, face ·es pale yellow, blue underneath, the roof of the :th many sharp teeth. It sings with a plaintive voice oung duck," wrote Garden. Linnaeus called it *Siren*, ı classical Greek mythology for the part-woman, :ters, who were supposed to lure sailors to :h their singing. The supply of specimens from .o an end when his plantation was confiscated erican Revolution and he was banished to England. ·ed, however, by having the fragrant *Gardenia* genus d after him – thanks to much lobbying of Linnaeus and John Ellis.

·*iren lacertina* is one of the largest amphibians in North America, up to 90cm long, though the tadpoles are little larger than those carnivore, feeding on invertebrates and small fish, the siren swims muddy bottoms of ponds and lakes using its single pair of legs. :cades after Alexander Garden first sent specimens to England as :re adult animals or in fact the larvae of an even larger salamander.

Set of scales. More than 22 million specimens, many of which are of **his·**

:ies in the twenty-first century oy conservation ethics and :vs designed to ensure :nt of living organisms and to !iversity. The growing oiodiversity is a valuable :ce has also resulted in ·oprospecting' regulations and intended to ensure that gnty over natural resources that economic benefits loiting biological resources uted.

)0 new specimens are added · collections each year from a ources. Some, including natode worms and fish, come ıal scientific expeditions; ased or donated from existing :imens of larger species often :lt of natural or accidental fiscations from illegal :ies that were collected in the mates, are now only added to they are accidental deaths or : have died in captivity. To acquisitions, the first phase of ıtre has been designed with

Out of the freezer. Edward Wilson and others risked their lives to collect these emperor penguin eggs during the severe Antarctic winter in the hope of shedding light on bird evolution.

the capacity to store 10 per cent more material than it currently holds.

Common organisms are still collected for scientific research, but many rare species are studied alive, in the field, using the latest techniques in recording and imaging. International collaboration and information exchange now lies at the heart of conservation efforts, and this increases the value of existing collections. In an age of rapid transport and information transfer, there is no need for large, duplicate collections to be held in many locations throughout the world. The priority now is to maximise the scientific value of those collections that already exist.

The majority of the specimens in The Natural History Museum are maintained for their scientific value, but there are also many that are simply irreplaceable items of national heritage. One particularly poignant set of specimens consists of three eggs of emperor penguins *Aptenodytes forsteri*. These were collected by Dr Edward Wilson and his colleagues Lieutenant Henry Bowers and Apsley Cherry-Garrard in 1911 during a five-week journey to the penguin rookery at Cape Crozier in Antarctica. The trip was undertaken in the depths of the Antarctic winter, and conditions were appalling: complete darkness and with temperatures below -50°C. The experience was later described in Cherry-Garrard's book *The Worst Journey in the World*, which he introduced with the memorable statement: "*Polar exploration is at once the cleanest and*

mportance, are preserved in alcohol in 450,000 jars. *From left to right:* The football fish (a deep-sea anglerfish), Darwin's lizards, Cook's fish and the tuatara lizards.

:ost isolated way of having a bad time which .ıs been devised."

It was hoped that the penguin embryos ·ould provide valuable scientific :formation on bird evolution, since :nguins were considered to be primitive ıd the species most likely to demonstrate :ıatomical similarities with reptiles during ıe development of their embryos. But the :sults proved inconclusive. In the words of :rd anatomist CW Parsons shortly :terwards: "*Unfortunately nothing decisive ıuld be expected from the collection of the three ·nperor embryos so close to one another in :evelopment as those which Dr Wilson and his colleagues obtained at such cost.*" Neither Edward Wilson nor Lieutenant Bowers lived to share Parson's disappointment – both perished with Captain Scott in their fatal trek to the South Pole a few months later.

Protecting and preserving

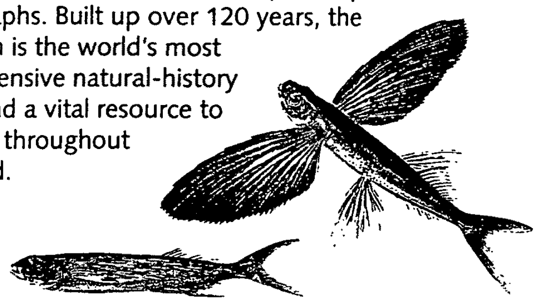
The Natural History Museum now houses more than 70 million scientific specimens, more than 60 million of which are of biological origin – which amounts to an irreplaceable scientific resource. There are 6 million botanical specimens, 28 million insects (including specimens of about half of all known insects) and 27 million specimens from the rest of the animal kingdom, including 95 per cent of all known birds. Included in the collections are pollen grains, dried skins, skeletons, birds' eggs and nests, pressed plants, wet and dry preserved specimens, microscope slides and frozen tissue samples in liquid nitrogen for studying DNA. As well as these biological specimens are very many valuable paintings, drawings, photographs and historical and scientific documents. The drawings of natural-history artist Ferdinand Bauer, for example, made on *HMS Investigator*'s expedition in 1801

"Reptiles should be preserved in spirit wherever practicable . . . 'n default of spirit the collector may use arrack, brandy, rum, or any other piritous fluid which . . . possesses the requisite strength . . . It is sometimes ound advisable to mix some emetic . . . or other disagreeable ingredient, vith the spirit, in order to deter pilferers from appropriating it."

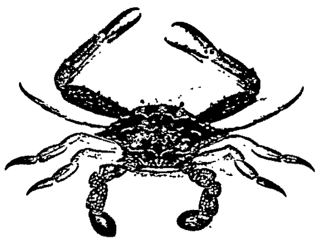
Ray Lankester, Director of The British Museum (Natural History), in the *Handbook of Instructions to Collectors* (1902)

ːry of life

ɿges on the atrium wall of the Darwin Centre are ·om the collection in the museum library, which s more than a million books, half a million works ɿd thousands of manuscripts, maps and ·aphs. Built up over 120 years, the ɔn is the world's most ɦensive natural-history .nd a vital resource to .s throughout ld.

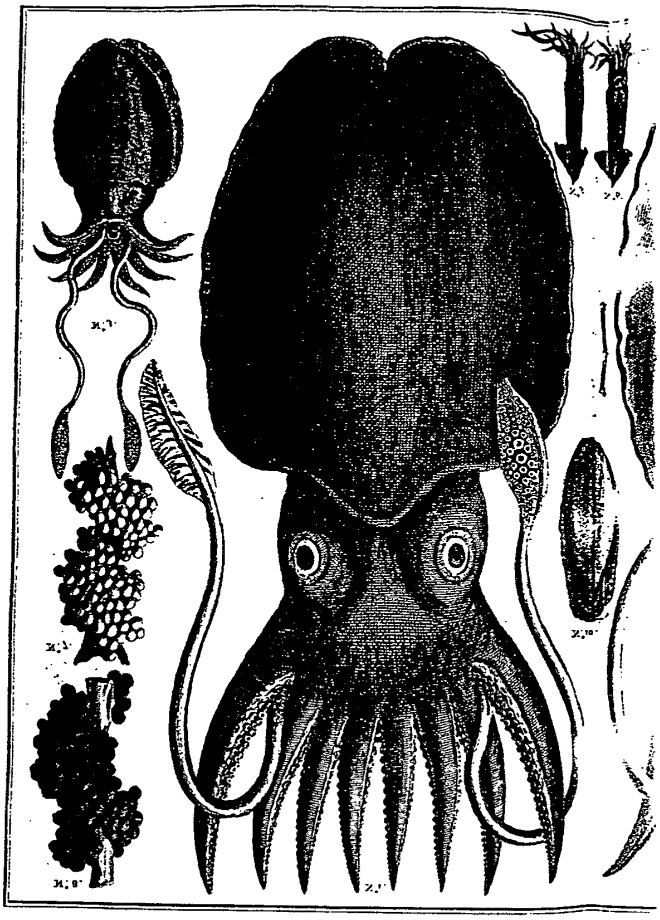


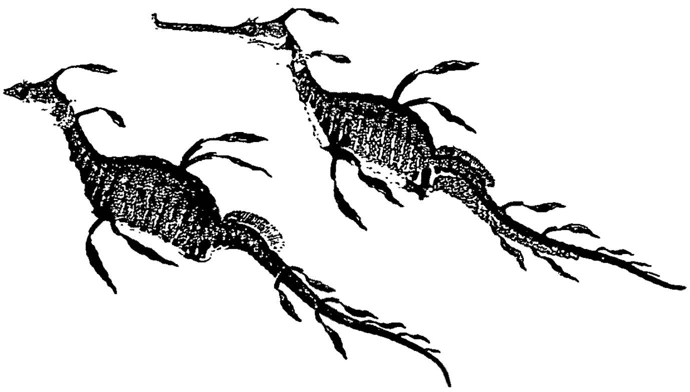
.-winged flying fish *Exocoetus* sp.
ǀ Bauer (1760-1826)
ɪerofoils, allowing the fish to leap clear of the water and glide long distances, especially when ·dfish and tuna predators. The French name for a flying fish – exocet, derived from the Latin ꞩ also given to the anti-shipping missile used in the Falklands War.

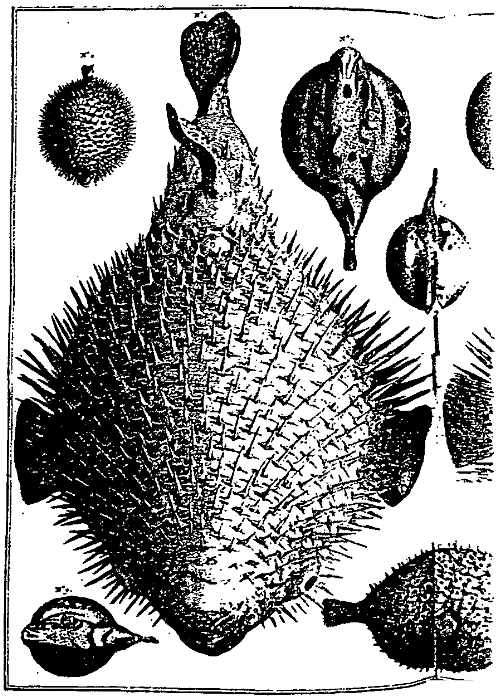


ˑrog *Litoria aurea*
! Bauer
.e this drawing, the species was as with many frog species, its :ndling. One surviving dney made headline news in as relocated at great expense Olympic facilities.

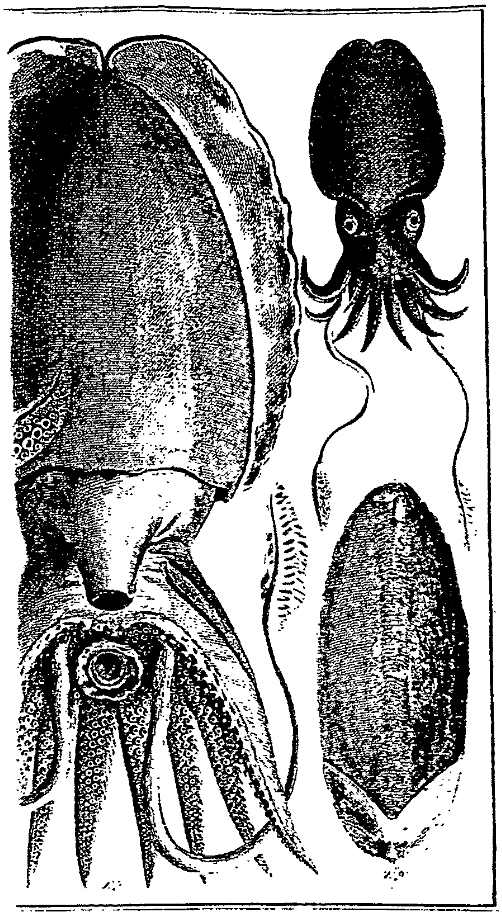
Blue swimming crab *Portunus pelagicus*
by Ferdinand Bauer
Linnaeus named this edible crab after *Portunus*, the Roman god of harbours. It lives in shallow water and mangrove swamps, reaching a body size (excluding legs) of more than 20cm across and is exploited commercially. Its last pair of legs are fringed and act as paddles.

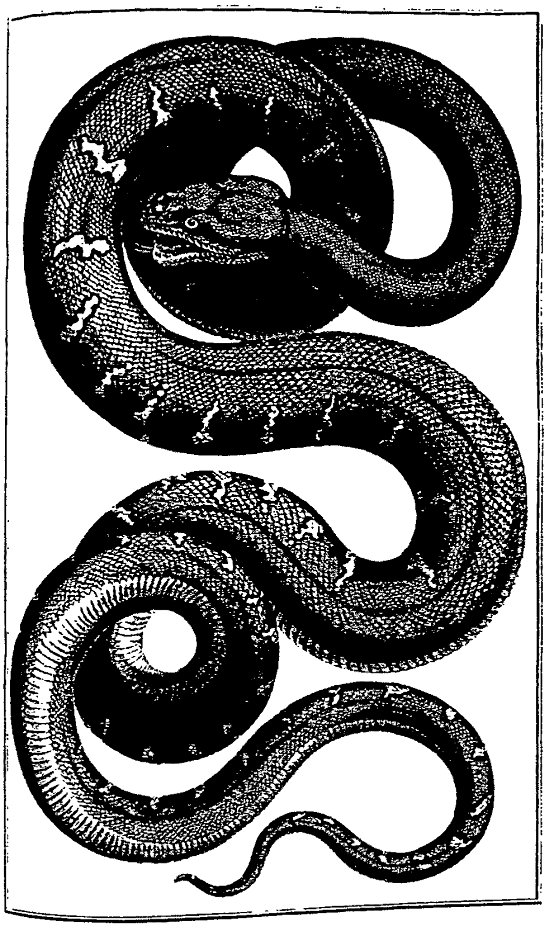


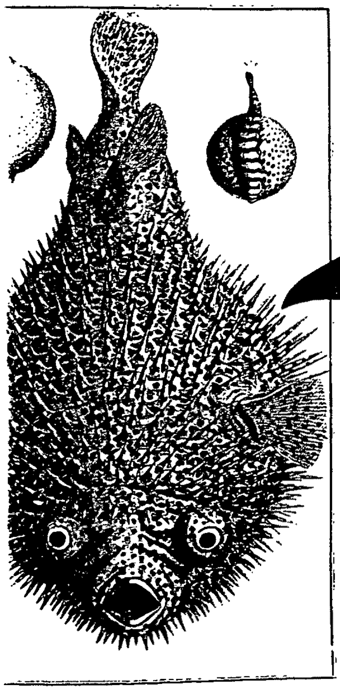




ˑagon *Phyllopteryx taeniolatus*
ǀ Bauer
among kelp-covered rocks and are endemic to Australian waters, where they are now protected. They :ed to seahorses, but unlike seahorses, they are poor swimmers, unable to clasp seaweed with their ɪre sometimes washed ashore after storms.





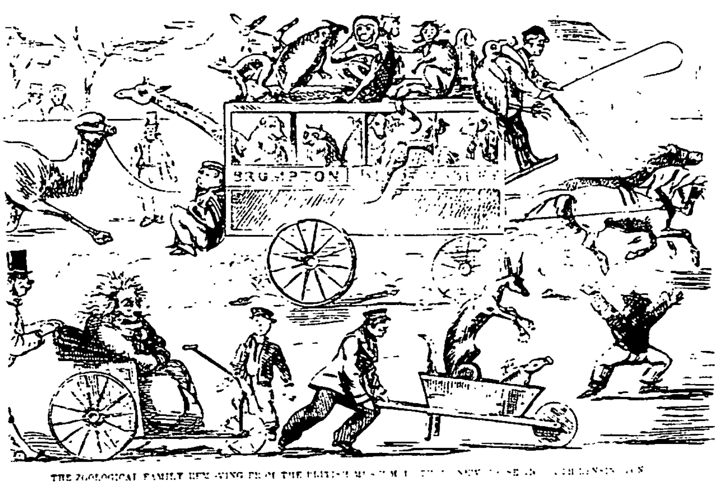


Squid
From Albertus Seba's *Thesaurus* vol. 3 (1759)
In Seba's day, stories abounded of sea monsters, and his *Thesaurus* contains some somewhat fanciful illustrations. These, however, are accurate depictions of squid. Tales of giant squid, capable of attacking ships, have long been told. Dead specimens are occasionally washed ashore, but live examples have yet to be found.

Snake
From Albertus Seba's *Thesaurus* vol. 3 (1759)
Albertus Seba (1665-1736) was a Dutch apothecary, who, like his contemporary Sir Hans Sloane, assembled a massive 'cabinet of curiosities.' He sold his first collection to Czar Peter the Great but assembled another, even larger one that was illustrated in four volumes of copper-engraved, hand-coloured plates.

Puffer and porcupine fish
From Albertus Seba's *Thesaurus* vol. 3 (1759)
When threatened by a predator, these fish inflate themselves by gulping water so that their spines become erect and prevent them from being swallowed. In Japan, pufferfish is an expensive delicacy, known as fugu, but it needs expert preparation – its liver contains a poison 1,250 times deadlier than cyanide.

Silky short-tailed bat
***Phyllostoma grayi* (now known as *Carollia brevicauda*)**
From *Zoology of the Voyage of the Beagle*, vol. 1-3
This is a common species in tropical and subtropical moist forests, where it feeds on fruit. Charles Darwin encountered it at Pernambuco, north of Bahia Blanca in Brazil, where he found the bats roosting in lime kilns.



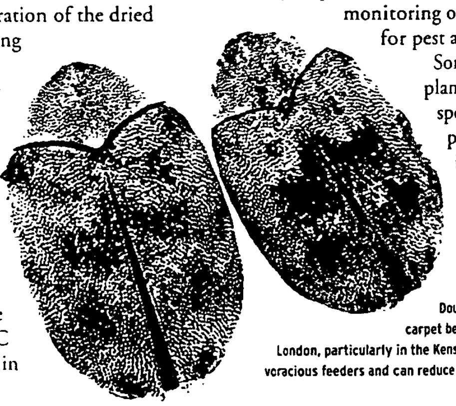
g history. In 1882, it took nearly 400 loads by horse-and-cart to move the collection; this time, each specimen, including the giant stingray, was moved by hand – that meant more than 10,000 trolley trips.

.ocument the little-known Australian
a and fauna, are exquisite and
sured by both scientific and artistic
:munities. The majority of Bauer's works
.iow held in the archives of The Natural
:ory Museum.

\ major task today is to curate and
:lop the existing specimen collections,
this has now become a science in its
: right. The curation of the dried
:imens, including
plants and
:cts that will be
.sferred into
se Two of the
win Centre
007,
ents
:icular
:lenges. Pests
a constant
:at. Quarantine
reezers at -30°C
. those present in newly arrived specimens, while storage of specimens in a constant, temperature-controlled environment reduces the rate of deterioration. Colours of dried specimens may fade with time but can be preserved by shielding them from bright light. But their chief enemy is the Guernsey carpet beetle *Anthrenus sarnicus* – its larvae can reduce a tray of pinned insects to dust. Regular monitoring of these collections for pest attack is essential.

Some 22 million of the plant and animal specimens are preserved in alcohol, in 450,000 jars. They range from 25,000 jars of microscopic plankton to large fish that are preserved in glass jars a metre tall and weighing 60 kilograms. These were previously housed in the old Spirit Building, now demolished, and were laboriously transferred to the new Darwin Centre, where they now sit on 25 kilometres of shelving in 3,500 cabinets.

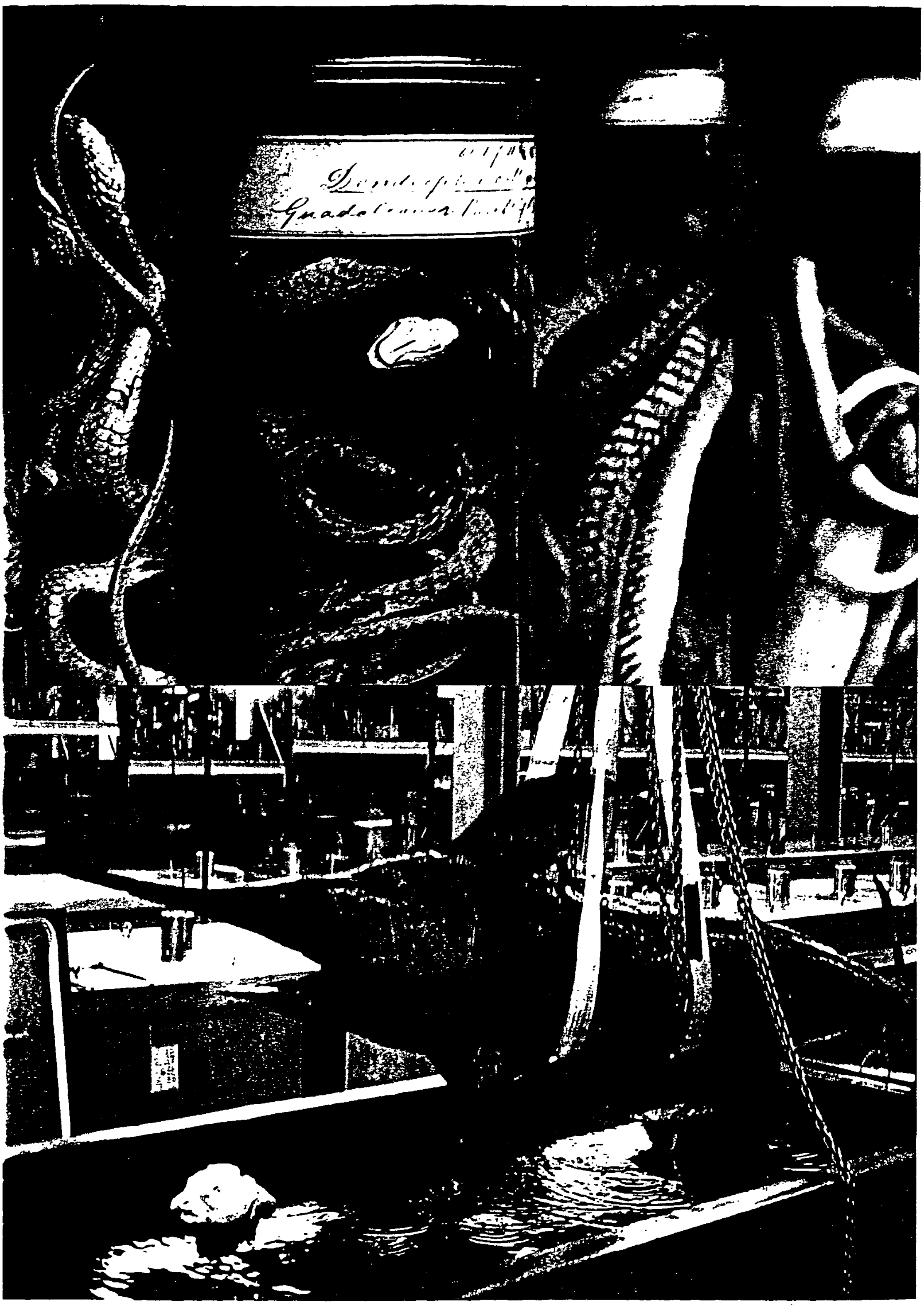
During the move from the British Museum in Bloomsbury to South Kensington, in 1882, two labourers and five attendants were employed to shift the specimens, making 394 trips by horse and cart over a period of 97 days. Moving the spirit collection into the Darwin Centre 120 years later was an even more daunting prospect, occupying 20 curators and their assistants every weekday for almost a year. Each specimen was packed by hand into crates and moved on trolleys across a temporary bridge from the old Spirit Building into its new accommodation. The staff made a staggering total of 10,000 trolley journeys. Fewer than 10 jars were broken, a remarkable achievement



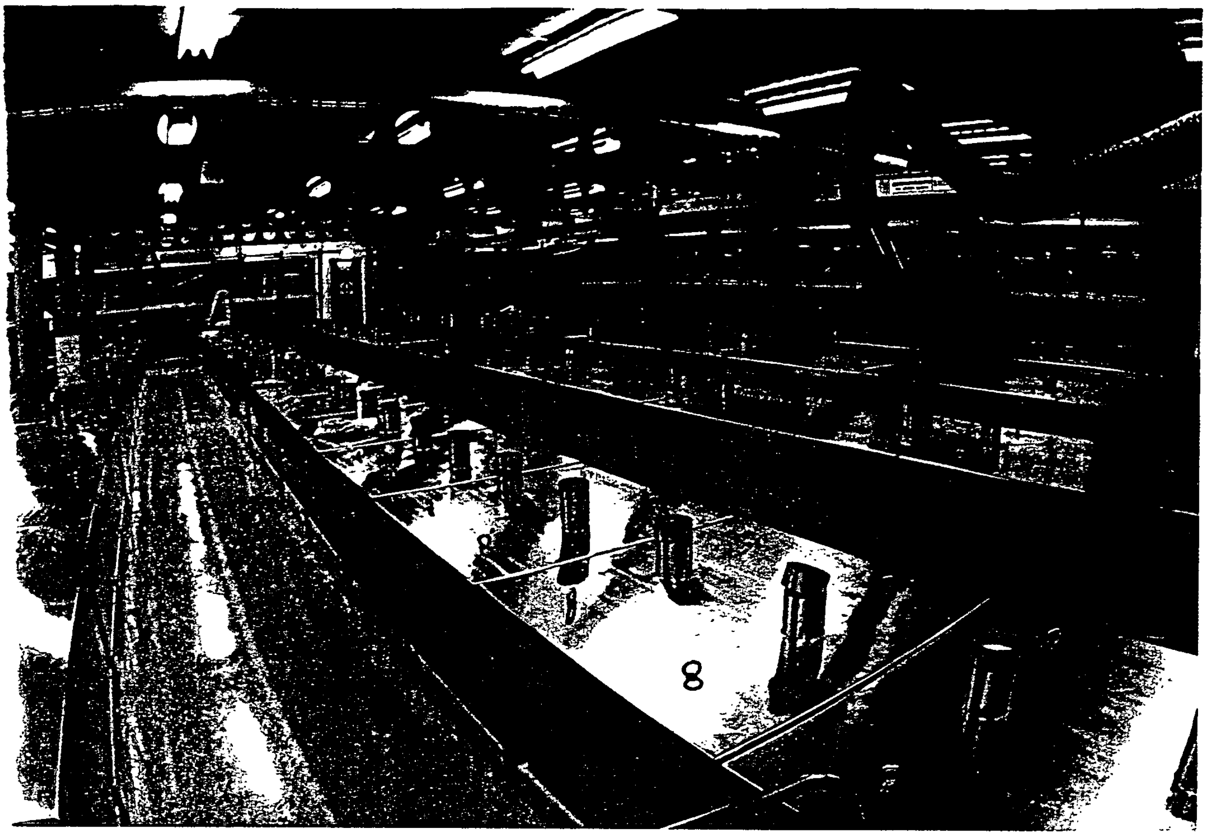
Double trouble. The Guernsey carpet beetle is well established in London, particularly in the Kensington area. Its larvae are voracious feeders and can reduce a tray of insects to dust.

"The instant one was perceived, it was necessary, in order to catch it, almost to tumble off one's horse; for in the soft soil the animal burrowed so quickly, that its hinder quarters would almost disappear before one could alight. It seems almost a pity to kill such nice little animals . . ."

Charles Darwin, collecting armadillos in Argentina, in his account of *The Voyage of HMS Beagle* (1845)



ırdfish. The specimen jars and tanks contain a wealth of creatures preserved in alcohol; many were actively collected, but this swordfish was washed up on a UK beach.



·e-of the-art storage. In the tank room, vast stainless steel baths of alcohol, ventilated with fume extractors, are home to the largest specimens in the collection, including sharks and giant conger eels.

ısidering that the glass in some of the
ge, Victorian jars is now extremely fragile.
ecimens were shifted shelf by shelf, after
·t ensuring that their classification was up
date and then mapping them to their
v location in the Darwin Centre.

Finally, the old Spirit Building, which had
ısed the jars of alcohol-preserved
cimens since the 1930s, was demolished –
h extreme care, since it stood only one and
alf metres away from the new building.

The opening of Phase One of the
rwin Centre begins a new era in the
tory of The Natural History Museum's
rit collection. For the first time, visitors
ı view this immense resource of preserved
cimens, which has been acquired
ough the work of generations of
uralists. The entire collection is stored in
·kness or low-light conditions at a

Going with the flow. Some of the oldest specimen jars are gradually becoming pear-shaped, as the glass slowly creeps downwards under the force of gravity.

constant 13°C in order to minimise the rate of deterioration of specimens and reduce evaporation of the alcohol in the jars. These conditions are also a key factor in the fire strategy for the building, maintaining the temperature safely below the flash point of the flammable alcohol.

One of the key tasks of the curators is to ensure that the alcohol in the jars is constantly topped up and any damaged jars or seals replaced. Almost all of the spirit collection, except for some delicate organisms such as jellyfish that must be kept in formalin solution, is preserved in 75 per cent alcohol, prepared by diluting industrial methylated spirits with distilled water. In total, the collection holds about 350,000 litres of alcohol, and supplies are pumped around the building from a central underground store.

' never had but only one to examine and the company who permitted me to make ıt the description insisted in their having the pleasure of eating it."

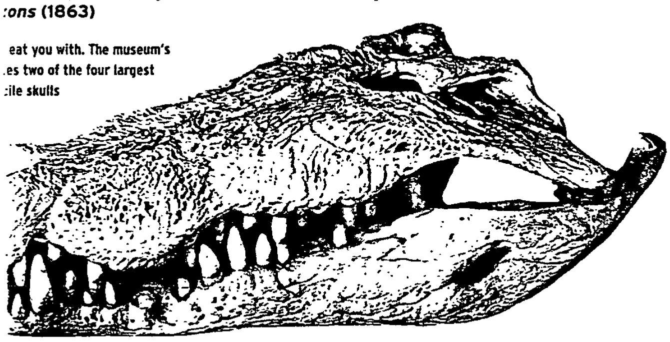
.teenth-century South Carolina naturalist Alexander Garden, explaining in a letter to Linnaeus why he could not send him a specimen of a rockfish

ɲ record-breakers

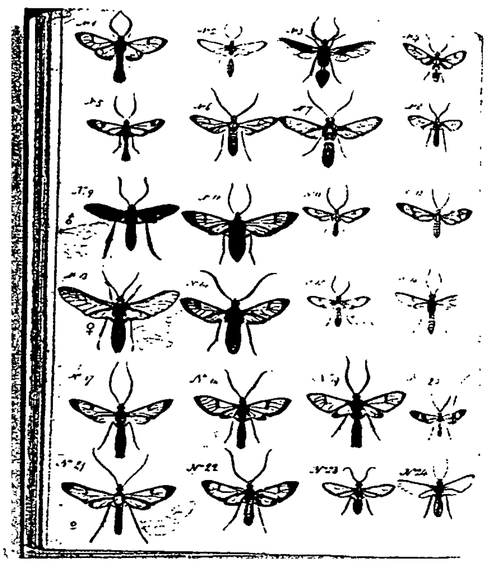
ɜe crocodile *Crocodylus porosus*, which lives in South-east Asia and northern
the largest of all crocodiles and alligators, and the museum collection includes two
ɜrgest skulls in existence. The smallest of the two was reputed to have come from a
ɲg specimen, though recent calculations suggest a length of six metres is more
sy to understand how a collector might exaggerate the size of one of these giant
ɜe excitement of its capture. The famous collector Henry Walter Bates vividly
ɜ perils of working in regions where large caimans, the South American equivalents
ɜ, lurked:

ɲen, during the greatest heat of the day, when almost everyone was enjoying his ɲap, took it into his head while in a tipsy state to go down alone to bathe... the ɜd, and a pair of gaping jaws, appearing suddenly above the surface, seized him ɜist and drew him under the water... The village was aroused: the young men... ɲarpoons and hurried down to the bank; but, of course it was too late, a winding ɜd on the surface of the water was all that could be seen... determined upon ɜhe monster was traced, and when, after a short lapse of time, he came up to e leg of the man sticking out from his jaws – was despatched with bitter curses."

ɜr Bates, describing an encounter with an alligator in *A Naturalist* ɜons (1863)



eat you with. The museum's ɜes two of the four largest ɜile skulls



True colours. Preserved specimens often fade over time, and so collectors' notebooks, such as the illustrations of Henry Walter Bates, made in Amazonia around 1850, can be very useful in identifying species.

ɜt jars, up to a metre high and ɜ than 60kg, are now housed ɜm on the ground floor of the ɜe, where there is a perpetual, oma of alcohol. Stored here ɜ fish, snakes and other of the jars are now so old that ɜme fragile and distorted as a ɜadul flow of glass under the ɜ.

ɜ specimens are stored in ɲg stainless steel tanks of ɜd with fume-extractors phants' trunks, which carry ɜohol vapour. Lifting one of ɜ lids using the overhead hoist Komodo dragons, crocodiles, ɜtles, swordfish, dolphins, ɜrom the Amazon, sharks and ɜls.

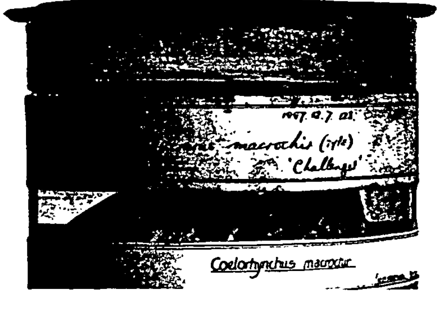
ɜize of these animals is ɜwever familiar some may ɜhrough television ɜew films ever convey the ize between a grotesque deep sea anglerfish, just centimetres long, and, say, a shark.

The largest specimen preserved in the tank room is a swordfish *Xiphias gladius*, which was found washed up at Avonmouth, near Bristol. Large fish have always been popular attractions for museum visitors, and in 1902, the *Handbook of Instructions to Collectors* noted that: *"some Sharks attain a length of 30 feet, and some Rays a width of 20 feet; and, according to very reliable reports, they may even exceed these limits. It is extremely desirable to obtain such gigantic specimens for museums... Specimens too large to be packed in barrels should receive a thorough dressing of salt and alum... they can then be dried."*

Swordfish attain a length of about 4.5m (15 feet), but about a third of that is their lethal 'sword,' with which they stun and slash their prey.

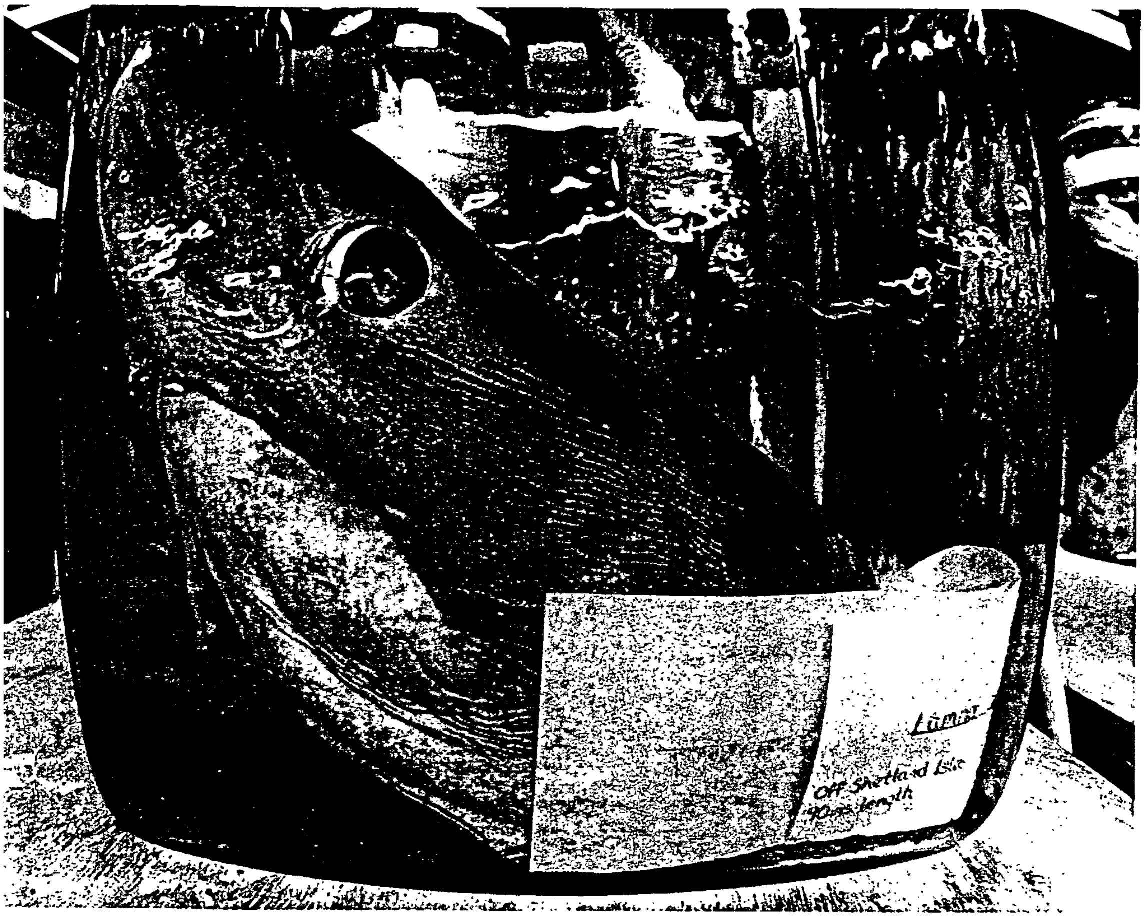
Seeing such creatures close up can be a uniquely moving experience. In one jar, floats the head of *Lamna nasus*, a porbeagle shark, its eyes clouded by alcohol, dulling the angry stare that must have confronted fishermen off the Shetland Islands in 1964, when they landed this threshing, 2.5-metre-long predator.

Some jars contain the internal organs of fish, reptiles and marine mammals, which have



Top marks. The precious type specimens – this one collected on the *Challenger* expedition – are kept in red- or yellow-topped jars or given coloured tags.

Mary Evans Picture Library



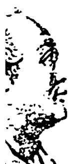
porbeagle shark was landed by fishermen off the Shetland Islands in 1964. At 2.5m long, it may not have been fully grown – adults can reach nearly 4m in length and live up to 40 years.

›ved to determine cause of death
}ate the parasites that lived in their
. In such cases, stomach contents
ten removed and preserved,
a valuable insight into an animal's
ıbits. The Darwin Centre is
with a pathology table, where
ımals such as stranded dolphins
:an be dissected and post-mortems
t.

The type specimens

The most valuable specimens of all are the 'types.' They are typically labelled with coloured tags or sit in jars of alcohol with painted red or yellow tops. These are the name-bearers for their species, the specimen or specimens that were first used to describe a particular species that was then new to science. There 850,000 of them in the museum's collections, and they have unique scientific importance. They represent a significant proportion of all species so far described on our planet.

Imagine, for a moment, that you are a scientist who finds a new crustacean on a coral reef in Belize. You search through the field guides and identification keys, but several features of the animal do not conform to the published descriptions. Could it be a new



"... a magazine of all the various kinds of plants, fish, birds, shells, seeds etc. hitherto collected: which made it vastly damp, dirty, crammed, and caused very noxious vapours"

Johann Reinhold Forster, describing his cabin on *HMS Resolution* during Captain Cook's second voyage to the South Seas (1772-1775)

·he museum's scientists. Each day, trained ·ead small groups of visitors on ..u-the-scenes tours through specimen .e rooms, providing a unique insight into : scientific work of one of the world's :atest natural history museums (see p35). It empting to speculate how the ghost of arles Darwin might react if he tagged along one of these tours.

He would no doubt be delighted to find ·wn familiar specimens – some collected : his voyage on *HMS Beagle* – so :ully preserved among the thousands of and bottles lining the shelves.

He would surely be amazed to see animals :overed long after his death, such as the ıy-finned coelacanth, which provides a link ·veen fish and the first walking amphibians – : would have confounded troublesome :es during Darwin's lifetime, who ·antly bayed for examples of evolutionary ng links.'

.le would also marvel at the sophisticated ntific resources in the research oratories, recognising familiar instruments n as microscopes and noting with ifaction new technologies, such as the lysis of DNA molecules, which have done nuch to reveal evolutionary relationships ·een species and confirm Darwin's theory lution.

.nd as a great communicator of science in ·wn lifetime, who wrote bestselling books ut his research findings for the general ·lic, he would certainly appreciate the care attention that has gone into ımunicating to visitors the thrill and ·faction of scientific discovery.

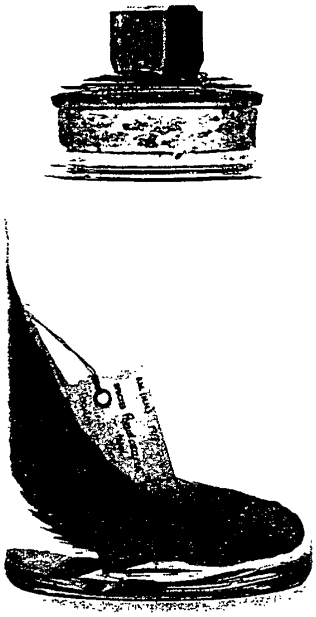
)ne can't help thinking that he would : sense of pride in lending his name to :erprise that encapsulates the spirit of osity and wonder which inspired his ı life's work and that he would perhaps just a little envious as he nodded his d in approval.

ıissing link. Arguably a step between fish and walking ıbians, the bony-finned coelacanth would have helped ·n to build his evolutionary theory – if only it had been ·ered before he died.

The first of its kind

The Darwin Centre holds collections of many specimens collected by its namesake, including this parrotfish that Darwin collected from the waters around Tahiti during his famous voyage on *HMS Beagle*. This was the first ever example of the parrotfish *Pseudoscarus lepidus* to be scientifically studied and described, and so represents the species in all further investigations. Such specimens, known as type specimens, are unique and represent the basis for all comparisons between closely related species.

Darwin observed the feeding habits of parrotfish in the waters around Keeling Island. "*Two species of fish, of the genus* Scarus, *... exclusively feed on coral... I opened the intestines of several, and found them distended with yellow calcareous sandy mud*," he wrote in his account of *The Voyage of the Beagle*. A significant proportion of the sand on tropical beaches with fringing coral reefs has passed through the guts of parrotfish.



Bottled treasure. One of many specimens collected by Darwin himself, this preserved fish is also valued as a type specimen – the first parrotfish to be described by scientists.

Richard Kalina

'While looking for marine animals, with my head about two feet above the rocky ore, I was more than once saluted by a jet of water, accompanied by a slight grating ›ise. At first I could not think what it was, but afterwards I found out that it was is cuttle-fish, which, though concealed in a hole, thus often led me to its discovery."

·s Darwin, *The Voyage of the Beagle* (1845)

TWENTY-FIRST-CENTURY SCIENCE

'h 350 scientists behind the scenes, The Natural History Museum has gained international recognition for its research. Now you can meet the scientists and talk about their current work.

ears of inquiry

experience of the Darwin :ll be a revelation, not just ɔu'll see much more of the vast of specimens than previously to the public, but also because e able to find out how these . are used by scientists in the .nd around the world.

.ourse of history, the primary e museum's collections has n the late seventeenth and early centuries – Sir Hans Sloane's .ssembling a collection of .tory curios was a fashionable sign ıess and wealth. It also helped to : of the world, perhaps by ıes in nature that might .'s grand plan. :hteenth century – :ain Cook, Joseph Banks .olleagues collected on voyages to the – was a great age of :pansion. During this !ecting plant, animal ıl specimens became for gauging the :onomic wealth of

ɔrian times, science :tual inquiry became a :ason to collect. By the time that .blished his *Origin of Species* in :ctions provided an essential .ıformation in the intellectual :derstand nature. Advancing ıderstanding, for human benefit :r to help conserve biodiversity, : most important reason for g and extending the museum's today.
) scientists who work at The story Museum, together with :archers who come to study the . are engaged in research projects globe, often in international ɔns. The Darwin Centre has ıed to provide state-of-the-art research facilities and to allow visitors to meet scientists and learn more about their projects.

At the cutting edge

Three of the five science departments at the museum will eventually be located in the Darwin Centre: zoology has already moved into Phase One, while entomology and botany will be re-housed in Phase Two, scheduled to open in 2007.

Research priorities in the museum are distributed within various major themes (outlined below), each of which has numerous programmes.

Biomedical sciences is the study of the systematics of organisms that cause diseases in humans and domestic animals, and so includes research into insects that spread these diseases.

Ecological patterns and processes is concerned with ecology and conservation, working towards an understanding of the ways in which organisms are distributed, how this changes through time and how environmental conditions control the changes.

Flesh crawler. Specimens are preserved and prepared in a variety of ways. Skeletons, for example, are cleaned using the beetles *Dermestes haemorrhoidalis* (left), the larvae of which devour decaying flesh.

Faunas and floras aims to describe and name the world's species, find out where they live and provide keys for their identification so that they can be conserved.

Environmental quality monitors natural and man-made changes in the environment, often using living organisms such as lichens to monitor environmental deterioration or improvement.

Systematics and evolution uses traditional and modern techniques to reveal the evolutionary relationships between species, which is essential for learning more about living organisms by making comparisons between them.

Earth materials, history and processes is concerned with geological research, including work on fossils.

There are two further themes, Collections Management and Museum Facilities, which provide the resources for maintenance and use of the collections and for the research facilities that underpin the work of all the museum's scientists. Visitors to the Darwin Centre will

Chris Sharp/Oxford Scientific Films

be able to meet scientists from all science departments of the museum and hear more about their work. From mapping diversity on a planetary scale to identifying minute worms in the depths of Loch Ness; from working with whales to battling against blood parasites – these scientists have earned the museum worldwide recognition for its work in understanding and conserving biodiversity.

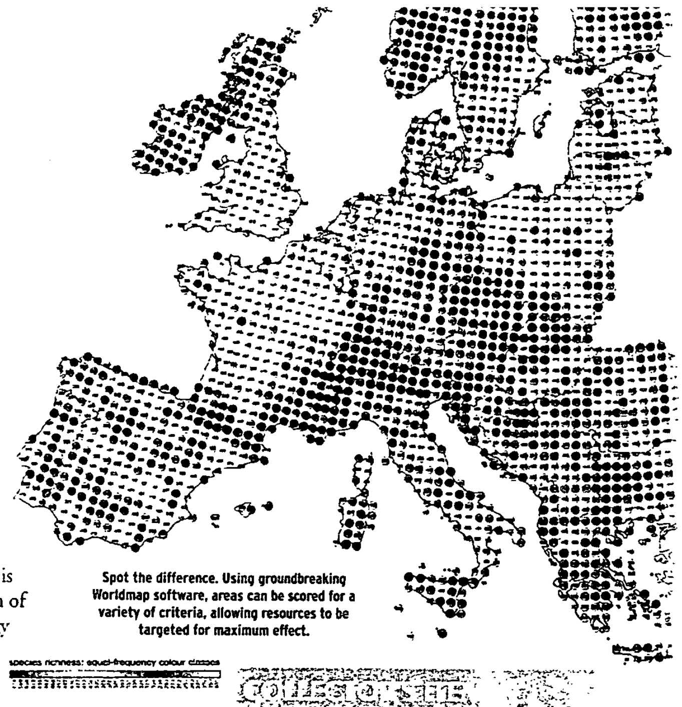
Mapping the priorities

The UN Convention on Biodiversity, aunched at the Rio Earth Summit in 1992 ınd revisited in Johannesburg in 2002, called 'or a co-ordinated approach to cataloguing .nd conservation of the world's biodiversity. t's an enormous task, which can only be ackled with national and international .ollaboration between scientists with a wide ange of specialist skills in the study of lifferent groups of living organisms. Establishing priorities for urgent action is ital, and tough decisions need to be taken .bout where to target scarce resources.

Worldmap is a programme of related rojects undertaken by researchers in the Biogeography and Conservation Laboratory, which combines ecological and systematic esearch to measure biodiversity and set riorities for conservation on a wide range of cales, from butterflies in an English county plant families across the planet. Simply armarking locations for conservation effort n the basis of the total number of species ey contain may not be the best way to pply effort if most of those species are ommon and widespread.

Worldmap software allows conservationists make calculations that take into account ther important factors, such as rarity, estricted distributions or the particular ollections of species (species complements) in ifferent localities. This means that they can armark areas for protection by a variety of iteria. For example, these can be areas that ontain the most vulnerable species or those otspots' of highest species diversity or ndemism richness (number of species that ccur nowhere else). The software package akes most effective use of the taxonomic and ogeographical knowledge that we have and can be constantly updated as new information becomes available.

In a world where only a limited range of conservation priority areas can be protected, it's essential to choose the right ones. Worldmap is a landmark application of information technology for assessing networks of areas with the highest levels of biodiversity, rare species and species complements. Those that score highly in all three criteria can be selected as high priority areas for maximum conservation effort.



Spot the difference. Using groundbreaking Worldmap software, areas can be scored for a variety of criteria, allowing resources to be targeted for maximum effect.

es for life. Coffee plantations that include shade-giving trees, ch as this one in Mexico, are much richer in biodiversity than the re common, clear-cut and intensively managed plantations.

Shady secrets

In its native Africa, coffee grows naturally as an understorey shrub. in the shade of taller trees, and this is the way in which coffee was cultivated in South America when it was first introduced as a crop.

El Salvador is the most deforested country in Latin America, which makes its shade forests ecologically valuable habitats, used both by native birds and those that migrate from North America. These forests also provide a valuable environmental service by reducing the risk of soil erosion and conserving water. But since the 1970s, more intensive cultivation of coffee in full sun, at higher plant densities and using intensive agricultural inputs has led to the felling of shade forests. The recent collapse in world coffee prices, to the lowest in history, has renewed shade-forest clearance.

Natural History Museum researchers are working alongside Salvadoran scientists to build a database of shade-forest biodiversity, for species ranging from trees and ferns to wasps and termites, as part of El Salvador's National Biodiversity Action Plan. The research programme, funded by the Darwin Initiative, is designed specifically to provide local fieldworkers with easy-to-use, non-technical keys and methods for monitoring biodiversity, written in Spanish, and to train Salvadoran scientists at the museum in London.

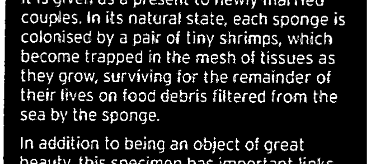
A fragile beauty

The glass sponge *Euplectella aspergillum* has romantic connotations in Japan, where it is given as a present to newly-married couples. In its natural state, each sponge is colonised by a pair of tiny shrimps, which become trapped in the mesh of tissues as they grow, surviving for the remainder of their lives on food debris filtered from the sea by the sponge.

In addition to being an object of great beauty, this specimen has important links with the museum's history. It was originally described in 1841 by Sir Richard Owen, the first director of The Natural History Museum after it moved to South Kensington.

Owen was one of the most accomplished anatomists of his era, especially in the field of reconstructing fossil skeletons of extinct animals. He is famous for a variety of other reasons, too, including coining the word 'dinosaur,' rejecting Darwin's theory of evolution and purchasing for the museum the specimen of Archaeopteryx, the reptile-like bird that remains one of the finest and most important fossils ever discovered.

This particular glass sponge was collected by Hugh Cuming during a voyage to the Philippines between 1836 and 1840. Cuming was an energetic field naturalist who, by his own account, collected 1,809 shells and 1,900 species of plants during the first year of his visit. "I trust you will be pleased with my labours," he ventured in a letter to Owen in 1837, "don't say I have been idle." The museum purchased Cuming's collections in 1866.



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A quick dip. Museum scientists are working closely with the Belize Government.

Working with the Belize Government, the museum scientists are recording and describing species and carrying out research that provides insights into the way in which this complex tropical ecosystem works. Species by species, the structure of the forest is being studied. Urn plants and mosses that live on the trees, ferns that live in the forest shade, spiders that hunt in the vegetation and predatory reptiles have all recently come under close scrutiny.

Other research projects here range from studies of migrant birds that use the forest to the interactions between parasitoid wasps and larvae of leaf-mining insects; from assessments of the genetic diversity in the tropical trees to the development of simple field keys for their identification. Eventually, staff at Las Cuevas will be able to build a detailed picture of the interactions between the forest's plants and animals.

Since its foundation in 1993, on the site of a former logging camp, the research station has grown into a complex of five buildings housing 30 researchers, with laboratories and reference collections of plants and insects.

The station has become a centre for education and training, hosting frequent conservation workshops. Now, via web-casts to the Darwin Centre, the scientists can communicate their latest findings to the museum's visitors – both those who come in person and virtual visitors from around the globe.

Nerve centre. Las Cuevas Research Station was set up following the Rio Earth Summit in a hotspot of tropical biodiversity.

Paradise won?

Many of the museum's research projects are collaborations between museum scientists and those from other institutions in the UK and overseas. In Ranong Province, Thailand, the museum is working with scientists from the Plymouth Marine Laboratory, Thailand's Kasetsart University, Wildlife Fund Thailand and the local Kampaun Fisheries Co-operative, in a European Union-funded project to study and protect coastal mangrove habitats.

Mangroves are important habitats, because they protect the coast from erosion during tropical storms, serve as nursery areas for marine life used as food by local people and attract tourists who come to see the rich variety of wildlife that lives there. In southern Ranong the dugong, a rare and elusive marine mammal, grazes among the underwater seagrass meadows, and green turtles nest on the region's sandy beaches.

But mangrove habitats are declining rapidly in South-east Asia, and since 1961, more than half of Thailand's mangroves have been lost, for example, through coastal redevelopment. The Ranong programme aims to survey local biodiversity, providing checklists and methods for monitoring the long-term health of the environment. One key element of the project is to involve local people in the ownership of the project from the outset, by developing a field studies centre and providing educational resources for schools, promoting biodiversity awareness among the local population. Ultimately, the project will provide information for the local community, conservationists and government organisations, which will help to ensure the survival of this wonderful coastal habitat.

In pursuit of parasites

There can be few organisms on Earth that are not afflicted by some form of parasite. As Jonathan Swift quipped, "So, naturalists observe, a flea/ has smaller fleas that on them prey,/ and these have smaller still to bite 'em, /and so proceed *ad infinitum*." There is, however, nothing amusing about many of the parasites that live on people or their livestock. Schistosomiasis, a debilitating disease that mainly affects children, is caused by a parasitic fluke, a schistosome, which lives in the bloodstream of 200 million

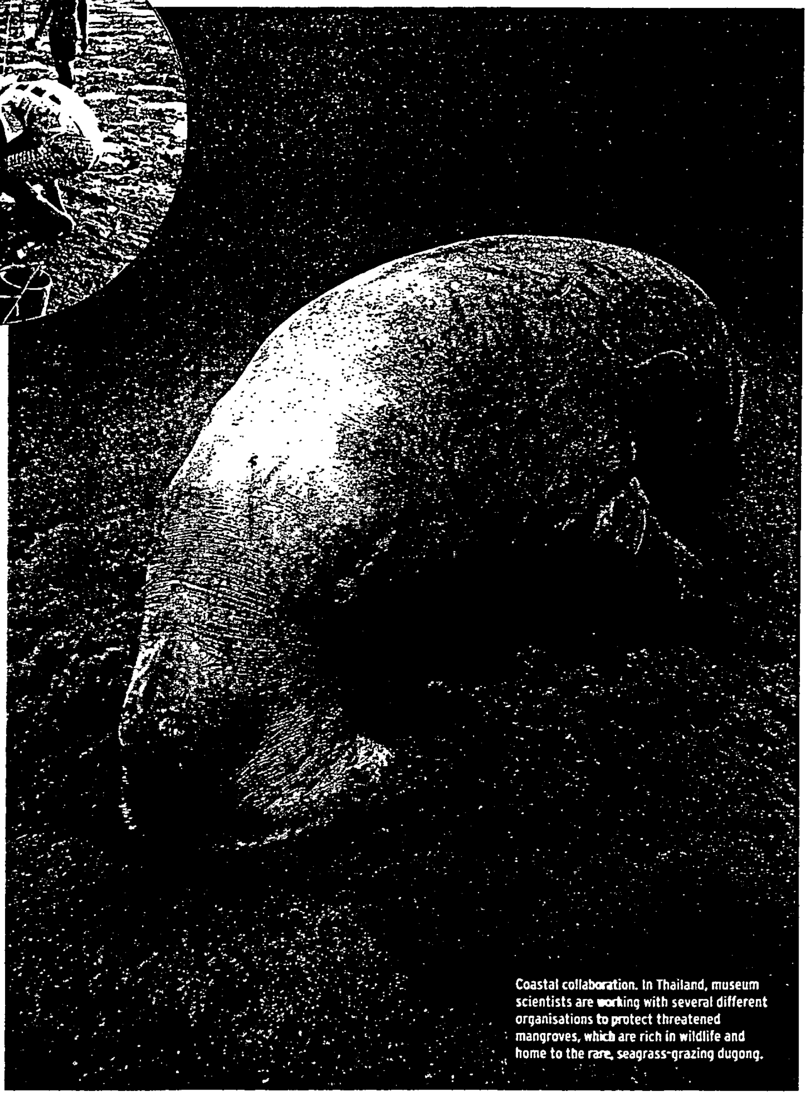
:ople in 74 ›untries in the :·eloping world. :ıe flukes spend ırt of their ·ecycle breeding in ·reshwater snail, :ıch lives in water ·lluted by human :rement containing the :asite's eggs. The parasites :ıetrate the skin of uninfected :ople who come into contact with .ter containing the host snails.

Controlling the disease is made :ticularly difficult because the snails and : parasites are genetically variable. :searchers in the museum, in collaboration :h Brazilian colleagues, have been .mining the parasite's DNA, which carries :enetic code, in order to determine how :istosomes from Africa differ from those in :er parts of the world. Ultimately, ·lecular taxonomic work like this can :vide information that will help in :geting more effective drugs and host-snail :ıtrol measures.

Meanwhile, in Bolivia entomologists from : museum are studying the fly that has :n responsible for the rapid spread of ·ine trypanosomiasis (sleeping sickness), ·ich arrived in South America relatively :ntly. The disease reduces productivity of :ictims, may cause pregnant cows to abort .ir calves and, in extreme cases, can be :l. In Africa, trypanosomiasis is :ısmitted by tsetse flies, but in Bolivia, the ; involved are tabanids – similar to the :ng horseflies that can make ramblers' lives :isery in Britain. The female tabanids feed :he blood of cattle and transmit the :panosome parasites in the process. The :en cattle swish their tails and stamp, :urbing the feeding flies, which then move :o another animal. So, once one cow is :cted, the parasite is spread rapidly :ough the whole herd by the tabanid flies.

By combining field studies with analysis :attle blood samples taken from tabanid :, scientists are building up a picture of insects' behaviour and biology. This will :p in devising insecticide treatments, :ative drug treatments for the cattle and :ıagement of herds to minimise the spread :he disease throughout Bolivia.

Occasionally, parasites can be put to :d use. They have long been used as :icators of the movement of fish stocks in shallow waters and may be of value in studying the movements of deep-sea fish. The rat-tail *Coryphaenoides armatus* is a metre-long fish that lives at depths of between 2,100 and 5,440 metres in the North Atlantic Basin in total darkness, low temperatures and enormous pressures. Following the movements of deep-sea fish such as this with conventional tags is impossible, because decompression kills the fish when they're brought to the surface. A zoologist at the museum is exploring the possibility of estimating fish movements by using parasitic worms that spend part of >



Pete Atkinson/NHPA; inset: Coastal Biodiversity in Ranong Project

Coastal collaboration. In Thailand, museum scientists are working with several different organisations to protect threatened mangroves, which are rich in wildlife and home to the rare, seagrass-grazing dugong.

Martin Hall

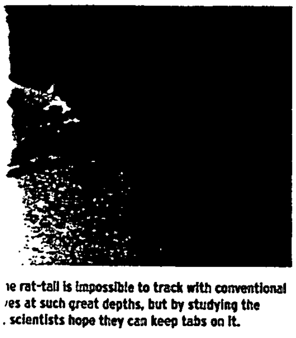
Feeding station. The bite of tabanid flies is quite painful to cattle, but swishing the flies off helps to spread disease in the herd.

of the most unusual – and ome – spirit-preserved mens in the museum are al parasites.

vorm. Inside a killer whale washed up on the ıst was a parasite possibly seven metres long.

ıale experts investigated the ıl contents of a 3.8 metre-long killer ashed up at Swanpool Bay in ı, Cornwall, in 1978, they discovered apeworm *Diphyllobothrium osum* that was longer than its host. worm, which had only ever been ce before, is too fragile to stretch measure, but the species grows to a f at least seven metres.

re alarming was the strange case of ortality among white-faced storm *Pelagodroma marina*. In 1970, ogists became alarmed when they ed 200,000 dead storm petrels in ham Islands, near New Zealand. s had all died with their legs tied by tough, fibrous material. After xamination, museum ogists pinpointed the cause – the ages of a parasitic fluke, *tes filiferus*, that had emerged in from their shrimp hosts into mats ed floating on the surface of the long-legged storm petrels feed by low over the water, feet pattering urface, and their legs had become ntangled, resulting in a natural on a vast scale.



ıe rat-tail is impossible to track with conventional ıes at such great depths, but by studying the . scientists hope they can keep tabs on it.

their lifecycle in the rat-tail and part in a series of alternative, unrelated hosts, each of which may occupy a different range from the rat-tails themselves. By identifying forms of the parasitic worm in rat-tails, the first steps are being taken in building the basis on which the technique of monitoring movements of shallow-water fish stocks can be extended into the deep sea.

High and dry

Every year, between 250 and 550 cetaceans – whales, dolphins and porpoises – are washed ashore or stranded around the coast of the UK. Most are harbour porpoises and dolphins, but occasionally, huge sperm, fin and minke whales turn up. Rarer casualties include the narwhal and the beluga, while in 1996, a tropical Fraser's dolphin was stranded in the Outer Hebrides.

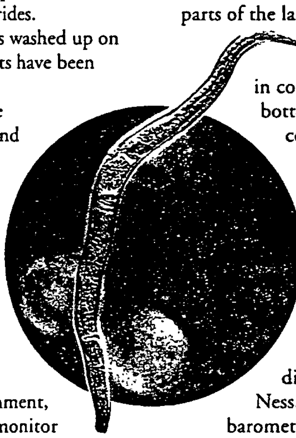
Since 1324, all cetaceans washed up on the English and Welsh coasts have been designated as 'fishes royal,' automatically becoming the property of the sovereign, and they cannot be disposed of without the permission of the Receiver of Wreck. Since 1913, The Natural History Museum has had first claim on cetacean carcasses, which form a valuable research resource.

The museum has been contracted by the Department of the Environment, Food and Rural Affairs to monitor strandings of live animals and dead carcasses, and to identify the species involved. This helps build up a picture of the distribution of these marine mammals in the seas around the UK. Carcasses in good condition can be transported for post-mortem examination in the new facilities at the Darwin Centre. This can establish cause of death, which may be natural, through pollution or as the result of accidents. The age of the animals can be calculated from growth lines in their teeth. Parasites in their lungs and stomach and on their skin reveal information about their state of health, and by undertaking the smelly job of investigating stomach contents, the museum's scientists can learn more about the animals' natural biology and feeding habits.

The museum's collections include specimens of marine mammals and large fish that have been washed up. Among these are two skulls of the Risso's dolphin *Grampus griseus* washed up on the Jersey coast in 1585. For information about the latest strandings, visit: **www.nhm.ac.uk/zoology/stranding/recent_events.html**

Loch Ness worms

Though the mythical Loch Ness monster remains as elusive as ever, scientists in the museum's department of zoology have found species that are probably new to science in the deep layers of mud on the bed of the loch. They're nematode worms, many of them less than a millimetre long, and they live in vast numbers in the top centimetre of sediment, even in the deepest parts of the lake, 214 metres below the surface. They are brought to the surface in cores taken from the lake bottom, with just one core containing as many as 274 worms of 27 different species. Nematode worms are valuable for monitoring the environment, because they respond quickly to changes, ranging from pollution to global warming. By cataloguing species abundance and diversity in the depths of Loch Ness, the zoologists have created a barometer for detecting and keeping track of the changing environment of the loch.



F Wanless/NHM Nematode Group

No monster. Loch Ness worms less than a millimetre long can help monitor environmental change.

Unsung heroes

As part of the UK commitment to the UN Convention on Biological Diversity, museum researchers are involved in a number of research projects that form part of the UK Biodiversity Programme.

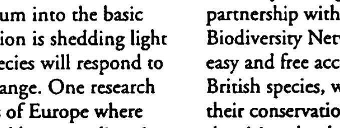
The UK Biodiversity Action Plan Initiative aims to concentrate conservation resources on those species most at risk, and the museum's scientists are focusing especially on invertebrate animals and on plants such as ferns, quillworts, mosses and lichens. These are species that are threatened and important but at risk of being lost

.tranded. Large whales are occasionally washed up on the UK coast, and their carcasses are a valuable research resource. This killer whale was found on the Mersey Estuary in October 2001.

hrough ignorance and neglect, because they .re less charismatic than, for example, vildflowers or birds. Without this deliberate .ttention, species such as the Killarney fern nd the mole cricket might simply disappear :om our flora and fauna.

By working closely with conservation ·rganisations such as English Nature, harities including PlantLife and nthusiastic and knowledgeable amateur aturalists, the museum's researchers aim to nsure that this will not happen. This is an rea of the museum's research where nterested members of the public can ›ecome involved – in recording schemes, or example, organised by the Wildlife 'rusts, natural history societies and onservation charities.

Our native flora is one of the most ntensively studied in the world, but there is lso a need to understand it better in a :uropean context. Some of our most ımiliar species – bluebells, for example – re rare in continental Europe. Though they ıay now be common in the UK, their ıture status – at a time when the climate is hanging – is a matter for concern. For :milar reasons, there is also concern about ne reverse situation, when common continental plants are rare in Britain. There is an urgent need to discover how our native plants will respond to the current phase of climate change, which will alter patterns of rainfall, extend the growing season and raise summer and winter temperatures. One crucial factor will be the level of genetic variability within species, which determines their capacity to evolve new forms capable of coping with the new conditions. By combining information on rarity with data on genetic variation, conservation bodies will be able to gain an insight into likely effects of climate change on plants and establish priorities for future conservation strategies.



Wanted.
If you spot a mole cricket, leave it where it is and tell the museum of your find: www.nhm.ac.uk/science/news/news.htm

Research at the museum into the basic processes of plant evolution is shedding light on the ways in which species will respond to future environmental change. One research strategy is to locate parts of Europe where the flora was least affected by great climatic upheavals in the past, such as the advance of glaciers during the Pleistocene (0.01 to 1.6 million years ago). These important areas constitute ancient 'safe havens' for high levels of diversity, where species survived until the glaciers retreated and re-colonisation of the barren land could begin, generating new species as they migrated northwards. Spleenwort ferns *Asplenium* spp. are particularly useful indicators of these European plant-biodiversity hotspots, which contain species such as the Mediterranean wall-rue fern, the ancestor of the wall rue *Asplenium ruta-muraria*, which grows commonly in Britain today.

Another rapidly developing area for the UK Biodiversity Programme is information technology, a vital tool in disseminating important information on our flora and fauna. One important goal is to establish in partnership with others a National Biodiversity Network. It will provide rapid, easy and free access to information on native British species, which will be important for their conservation. This is an extension of the vision that has driven the development of the Darwin Centre – making the museum's scientific information resources available to everyone. ■

xploring your world

The Central Hall (Life Galleries)

/er you want to know about the natural world, you d the answer at **The Natural History Museum.** g more than 70 million specimens from all over ›be, the Museum is dedicated to promoting the ery, understanding, responsible use and nent of the world around us.

The Natural History Museum,
Cromwell Road, London, SW7 5BD
Admission Free
Open: Monday to Saturday, 10am–5.50pm; Sunday, 11am–5.50pm

:getable, mineral . . .

japing jaws of Tyrannosaurus rex ›saurs exhibition to a tiny eyelash : *Creepy Crawlies* exhibition, the Life Galleries reveal the myriad ı living and extinct, that has ›n our planet. In the Earth /ou can explore the dynamic eath your feet, experience an e and see what happens when a upts.

: to see

ys in the Life and Earth Galleries :w state-of-the-art Darwin Centre emented by a regular e of special exhibitions t the year.

in the footsteps of dinosaurs

: *The Feathered Dinosaurs of* :als the missing link between and birds. For more than 140 ıtists argued modern birds ›m predatory dinosaurs. But the proof?

·l exhibition *Dino-Birds* ıe key to the mystery – the 4-million-year-old Fuzzy sil plus another 12 dinobird oan from The Geological f China.

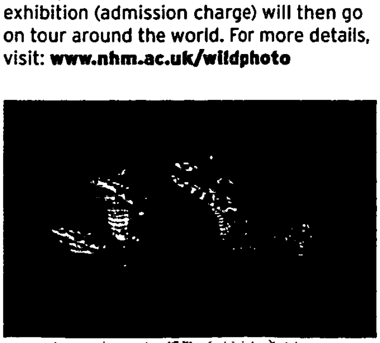
st £5 (£3 for concessions), and tion runs until 5 May 2003. For ormation and to book tickets, **.nhm.ac.uk/dinobirds**

Captivating imagery

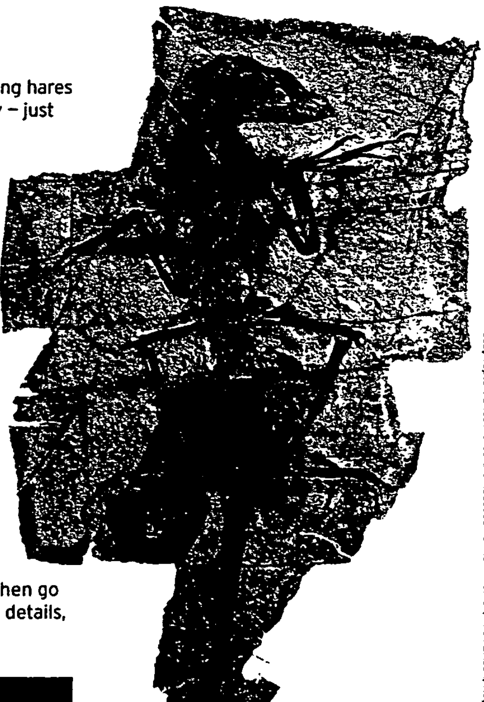
A leopard under a rising moon, boxing hares and an orang-utan cradling her baby – just some of the past winners of the BG Wildlife Photographer of the Year title.

This annual competition, organised by The Natural History Museum and *BBC Wildlife* Magazine and sponsored by BG Group, is now in its nineteenth year. Open to both amateur and professional photographers, it is the most successful event of its kind in the world, attracting more than 18,500 entries from over 60 countries.

Running from 19 October 2002 to Spring 2003 at The Natural History Museum, the *BG Wildlife Photographer of the Year 2002* exhibition (admission charge) will then go on tour around the world. For more details, visit: **www.nhm.ac.uk/wildphoto**



by Theo Allofs, Highly Commended 2002



Fuzzy raptor: a feathered dromaeosaur © Mark Norrell, Mick Ellison, Keqin Gao, AMNH

To find out more about the work of The Natural History Museum and its range of exhibitions and events ☎ 020 7942 5000 or visit www.nhm.ac.uk

SEE IT FOR YOURSELF

Ever wanted to go behind the scenes at The Natural History Museum, to explore its vast, historic collections, to meet its scientists and find out about their latest research? Now, for the first time, you can.

hat's on offer?

om 30 September 2002 – the opening of ıase One of the Darwin Centre – you can:

view fascinating and historic specimens ver before seen by the public;

use touch-screens to learn more about entific research at the museum and the portance of this work today;

take guided tours among the museum's st collections;

meet the museum's scientists.

ırwin Centre Explore

ıere will be 14 Darwin Centre Explore tours the collections every day. Tours are suitable adults and children aged 10 or over.

Darwin Centre Live

Darwin Centre Live events with scientists take place daily at 11.30am and 2.30pm. For a full events listing, ☎ 020 7942 5000 or visit: **www.nhm.ac.uk/darwincentre**

How much does it cost?

Admission to the Darwin Centre and its tours and live events are free.

Do I need to book?

Places can be booked on arrival at the museum. A limited number of pre-bookable tickets for Darwin Centre Live and Explore are available at **www.nhm.ac.uk/darwincentre** (booking fee).

Getting there

● Visitor access to the Darwin Centre is via the main Natural History Museum entrances. ● The museum is on Cromwell Road, London SW7 5BD ☎ 020 7942 5000. ● The nearest underground station is South Kensington (Circle, District and Piccadilly lines). Bus routes 14, 49, 70, 74, 345 and C1 have stops near the museum. ● Limited free, bookable car-parking is available for disabled visitors ☎ 020 7942 5888 (24hr service).

Opening times

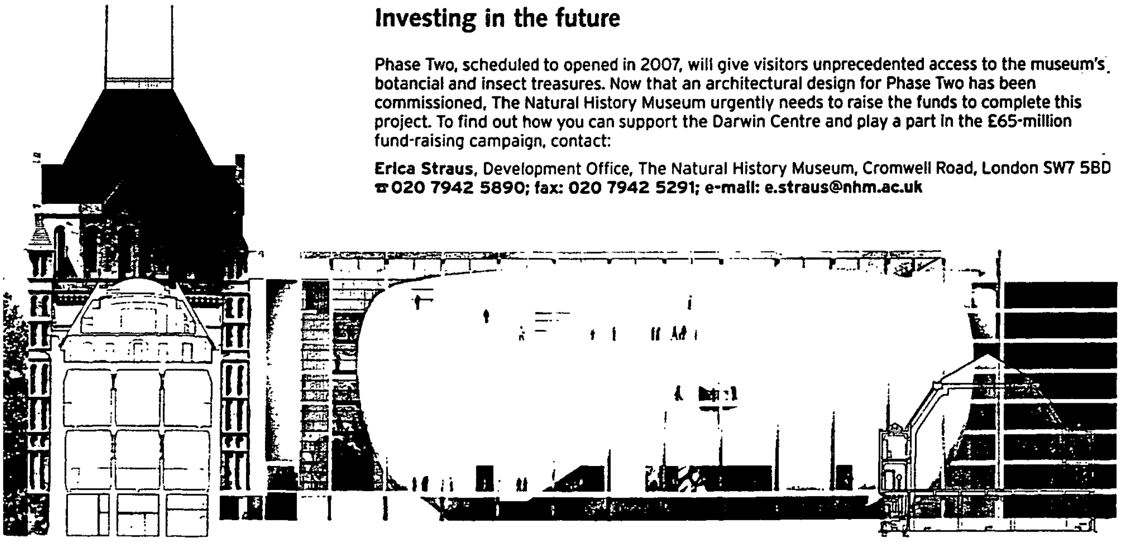
Monday to Saturday 10am-5.50pm
Sunday 11am-5.50pm
Closed on 24, 25 and 26 December.

HE DARWIN CENTRE: PHASE TWO

Investing in the future

Phase Two, scheduled to opened in 2007, will give visitors unprecedented access to the museum's botancial and insect treasures. Now that an architectural design for Phase Two has been commissioned, The Natural History Museum urgently needs to raise the funds to complete this project. To find out how you can support the Darwin Centre and play a part in the £65-million fund-raising campaign, contact:

Erica Straus, Development Office, The Natural History Museum, Cromwell Road, London SW7 5BD
☎ 020 7942 5890; fax: 020 7942 5291; e-mail: e.straus@nhm.ac.uk



CF Møller Architects

Shaping the future. Inside Phase Two, almost twice as big as Phase One, visitors will have access to millions of botanical and insect specimens never before seen by the public.

Museum of Archaeology and Anthropology

The Museum contains large and important collections of archaeological and anthropological material from all parts of the world. The archaeological collections from all periods include significant collections from Palaeolithic Europe, Asia and Africa; Precolumbian Central and South America; early civilizations of the Mediterranean; and British archaeology. The world-renowned anthropological collections include important collections from the South Seas, West Africa and the Northwest Coast of North America; historic collections from the 18th century; and extensive photographic collections from the 19th and 20th centuries.


Anthropology Gallery

ADMISSION FREE

OPENING TIMES
Tuesday to Saturday 2pm – 4.30pm
The Museum is closed at Christmas and Easter and on most public holidays.

ADDRESS
Downing Street
Cambridge CB2 3DZ

Tel (01223) 333516
Website http://cumaa.archanth.cam.ac.uk/

Museum of Classical Archaeology

The 'Ark' houses one of the largest collections of plaster casts of Greek and Roman statues in the world – over 600 casts of almost all the major pieces of classical sculpture. The collection was gathered together in the late nineteenth century to provide material for studying ancient art in Cambridge (the Victorians called it their 'archaeological laboratory'). The museum is part of the Faculty of Classics and is still used for University teaching; it also welcomes visitors and (pre-booked) school parties.


NIGEL CASSIDY, MUSEUM OF CLASSICAL ARCHAEOLOGY
Cast of the Farnese Herakles

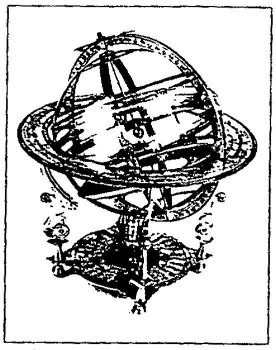
ADMISSION FREE

OPENING TIMES
Monday to Friday
10am – 5pm
Saturdays in University Term
10am – 1pm

ADDRESS
Sidgwick Avenue
Cambridge CB3 9DA

Tel (01223) 335153
Website http://www.classics.cam.ac.uk/ark.html

Whipple Museum of the History of Science



18th century Armillary Sphere

The Whipple Museum is a pre-eminent collection of scientific instruments and models, dating from the Middle Ages to the present. Microscopes and telescopes, sundials, early slide rules, pocket electronic calculators, teaching and demonstration apparatus, as well as laboratory equipment, are included in this outstanding collection. The main gallery of the Museum is housed in a large hall with Elizabethan hammer-beam roof-trusses, built in 1618 as the first Cambridge Free School. Two other galleries have recently been redesigned: 'An University within Ourselves' focuses on sciences in 18th century Cambridge colleges; the 'discover' is a reference collection displaying a wide array of scientific instruments. The Museum is part of the Department of History and Philosophy of Science and plays an important role in the Department's teaching and research.

ADMISSION FREE

OPENING TIMES
Monday to Friday 1.30pm – 4.30pm.

The Museum is not always open during the University vacations and visitors are advised to check beforehand.

ADDRESS
Free School Lane
Cambridge CB2 3RH

Tel (01223) 330906

Website http://www.hps.cam.ac.uk/whipple

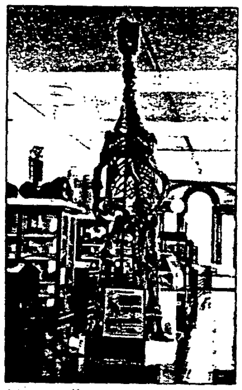
The Sedgwick Museum of Earth Sciences

One of the University's many hidden treasures, and actually its oldest museum, the Sedgwick is packed full of fossils with over 1 million in its collection. These range from the earliest forms of life over 3000 million years old through huge ammonites, giant marine reptiles, dinosaurs and a hippopotamus only 125,000 years old from the nearby Barrington gravel pit, a striking testimony to climate and environmental change. The museum started with Dr John Woodward's bequest of his fossil collection in 1728 (it's still on display in its original cabinets) and includes Charles Darwin's *Beagle* rocks. A stunning new mineral gallery shows minerals and gemstones in all their colourful glory.

ADMISSION FREE

OPENING TIMES
Monday to Friday
9am – 1pm and
2pm – 5pm
Saturday 10am – 1pm

CONTACT
Downing Street
Cambridge CB2 3EQ



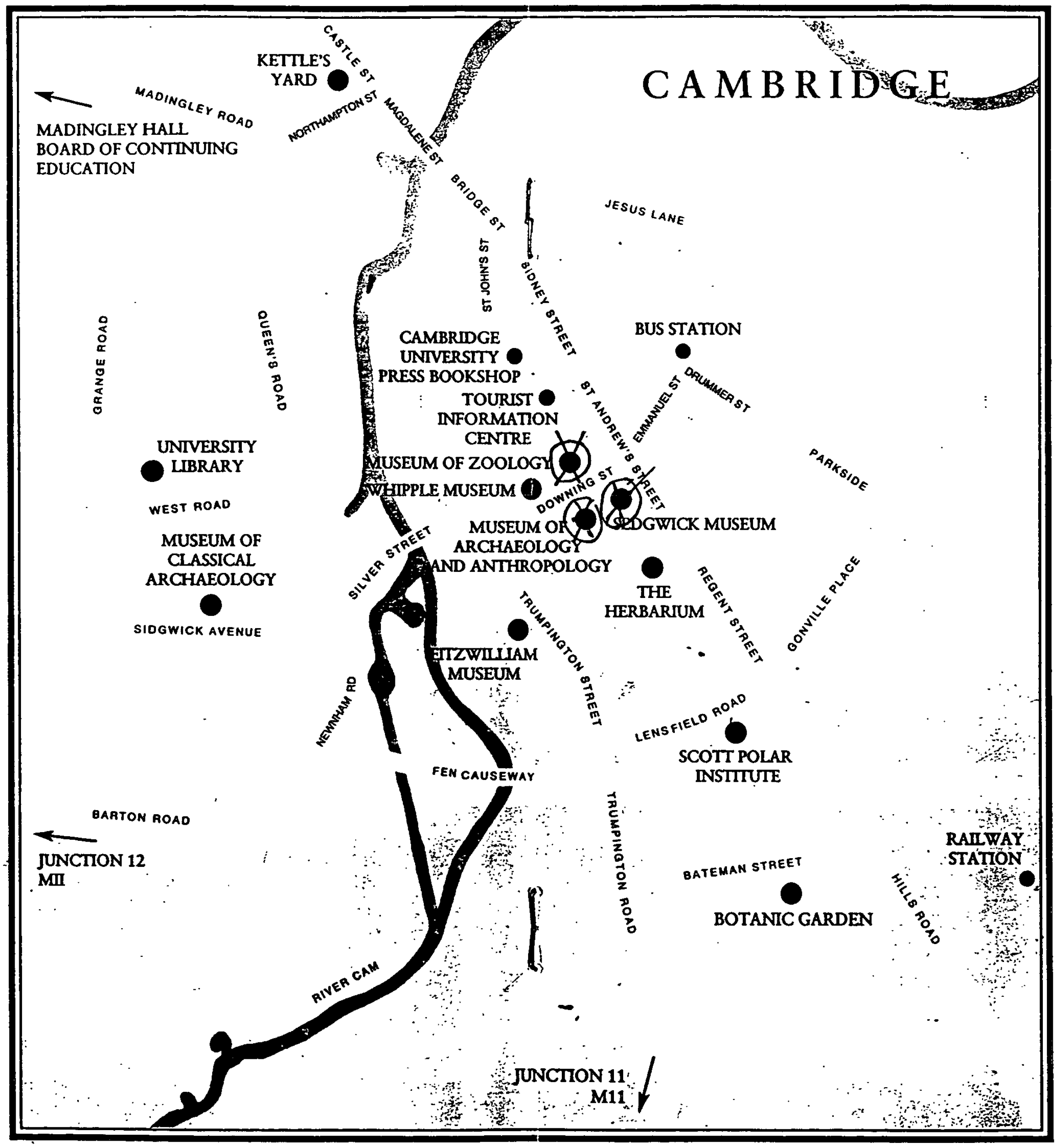
SEDGWICK MUSEUM

Main Hall

Tel (01223) 333456
Website http://www-sedgwick.esc.cam.ac.uk

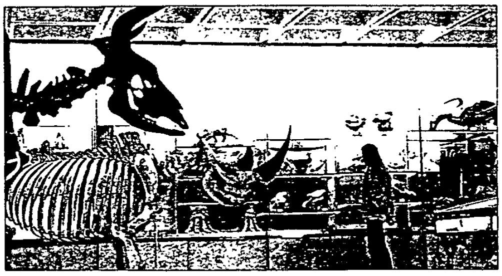
An ammonite from the collection

MARK MNISZKO


CAMBRIDGE
KETTLE'S YARD
MADINGLEY ROAD
MADINGLEY HALL
BOARD OF CONTINUING EDUCATION
CASTLE ST
NORTHAMPTON ST
MAGDALENE ST
BRIDGE ST
JESUS LANE
ST JOHN'S ST
SIDNEY STREET
GRANGE ROAD
QUEEN'S ROAD
CAMBRIDGE UNIVERSITY PRESS BOOKSHOP
BUS STATION
TOURIST INFORMATION CENTRE
ST ANDREW'S STREET
EMMANUEL ST
DRUMMER ST
UNIVERSITY LIBRARY
MUSEUM OF ZOOLOGY
WHIPPLE MUSEUM
DOWNING ST
PARKSIDE
WEST ROAD
MUSEUM OF ARCHAEOLOGY AND ANTHROPOLOGY
SEDGWICK MUSEUM
MUSEUM OF CLASSICAL ARCHAEOLOGY
SILVER STREET
THE HERBARIUM
REGENT STREET
GONVILLE PLACE
SIDGWICK AVENUE
TRUMPINGTON STREET
FITZWILLIAM MUSEUM
NEWNHAM RD
LENSFIELD ROAD
SCOTT POLAR INSTITUTE
FEN CAUSEWAY
BARTON ROAD
JUNCTION 12 MII
TRUMPINGTON ROAD
BATEMAN STREET
BOTANIC GARDEN
RAILWAY STATION
HILLS ROAD
RIVER CAM
JUNCTION 11 M11

University Museum of Zoology

The University Museum of Zoology, reopening in October 2001 after refurbishment, displays a great range of recent and fossil animals, emphasising the structural diversity and evolutionary relationships among the animal kingdom. The collections were accumulated from 1814 onwards, and include many specimens collected by Charles Darwin. They are now housed in a spacious modern building on two floors. The lower gallery presents a striking array of mammals, many as mounted skeletons which are appreciated as much by art students as biologists. This gallery also houses a near-comprehensive display of British birds. The upper gallery houses systematic displays of the major animal groups, exhibits that trace the origin and evolution of land vertebrates (not just dinosaurs!), and a notable collection of beautiful shells. To find the museum, look for the spectacular whale skeleton, hung above the entrance and visible through the archway from Downing Street.


UNIVERSITY MUSEUM OF ZOOLOGY

Rhinoceros skeleton from the collection

ADMISSION FREE

OPENING TIMES
Monday to Friday 10am – 1pm and 2pm – 4.45pm during University vacation.
2pm – 4.45pm only during term time.

ADDRESS
New Museums Site
Downing Street
Cambridge CB2 3EJ

Tel (01223) 336650
Email umzc@zoo.cam.ac.uk
Website
http://www.zoo.cam.ac.uk/museum

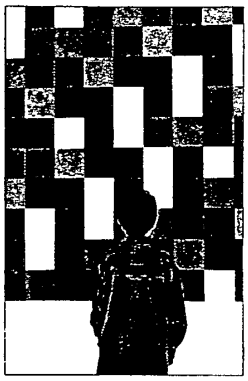
Kettle's Yard

Kettle's Yard is the former home of Jim and Helen Ede and houses the fine collection of art, from the early part of this century, which they gave to the University. Artists represented include Ben Nicholson, Christopher Wood, Alfred Wallis, David Jones, Barbara Hepworth, Henry Moore and Henri Gaudier-Brzeska.

There is a separate gallery for exhibitions of contemporary art, which are widely advertised. Each exhibition is accompanied by a lively programme of lectures, workshops and discussion groups.

ADMISSION FREE

OPENING TIMES
The house is open from Tuesday to Sunday
2pm – 4pm,
1.30pm – 4.30pm during the summer.
The gallery is open from Tuesday to Sunday
11.30am – 5.30pm

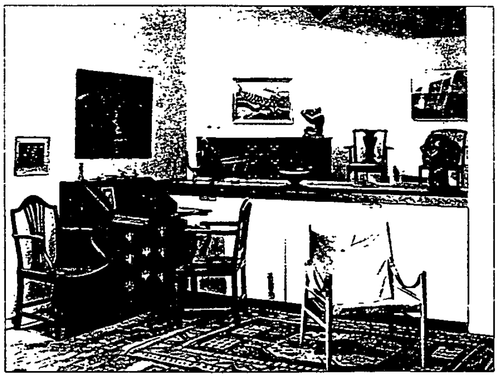


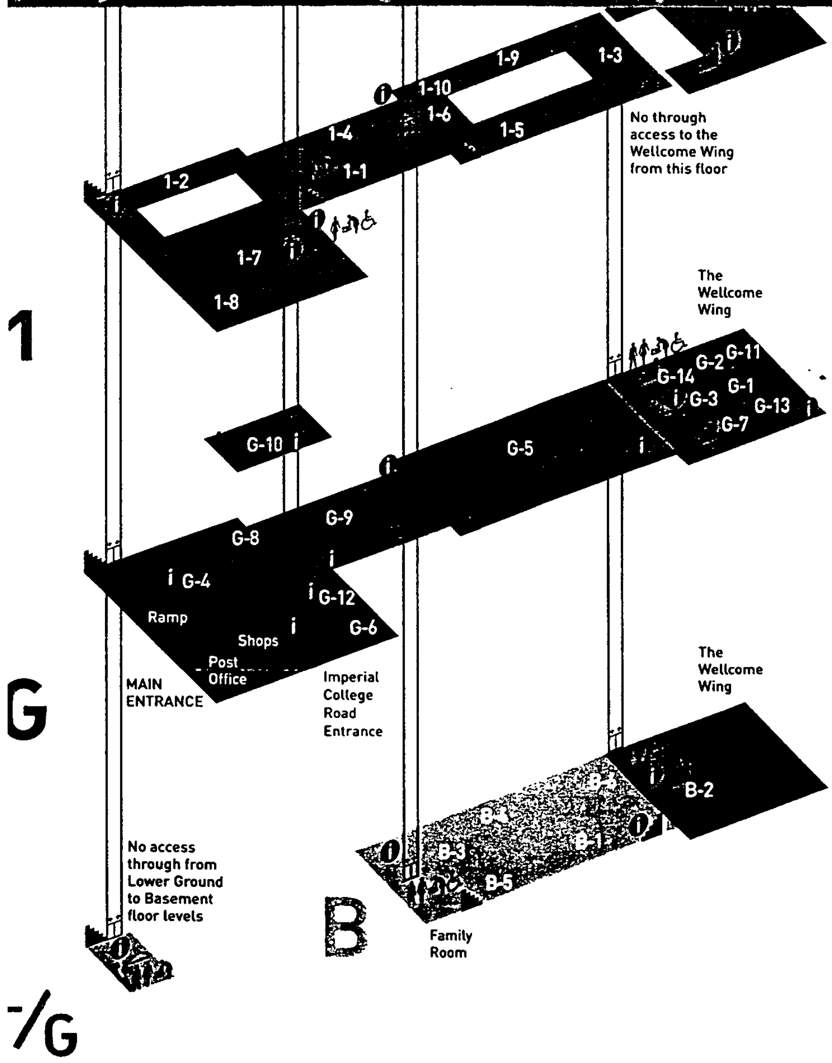
An exhibition in the gallery

ADDRESS
Castle Street
Cambridge CB3 0AQ

Tel (01223) 352124
Website
http://www.kettlesyard.co.uk

Downstairs, house extension


KETTLE'S YARD, UNIVERSITY OF CAMBRIDGE



Challenge of Materials	1-2
Food for Thought	1-3
Gas	1-4
Megabite Picnic Area	1-5
Surveying	1-6
Telecommunications	1-7
Temporary Exhibition Area	1-8
Time Measurement	1-9
Weather	1-10
Who am I?	1-11

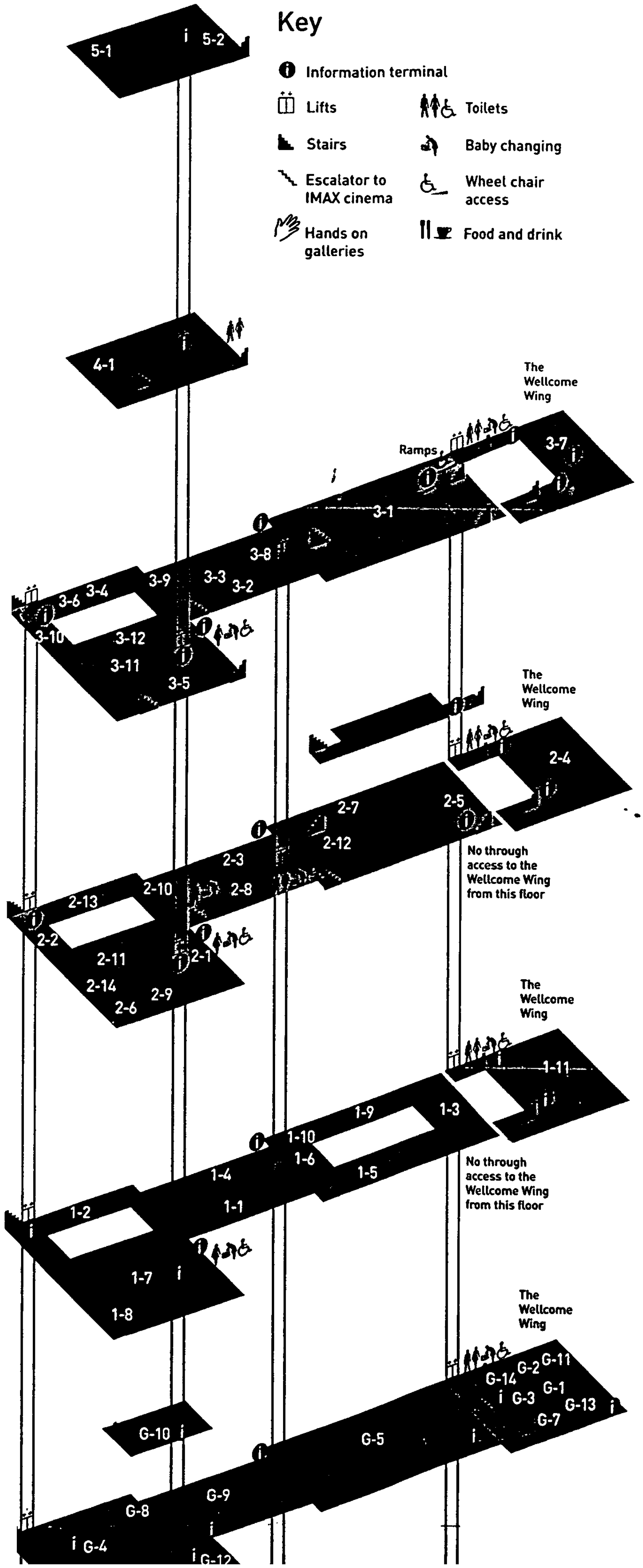
Ground Floor

Antenna	G-1
Deep Blue Café	G-2
IMAX Cinema Entrance	G-3
Information Desk	G-4
Making the Modern World	G-5
Museum Café	G-6
Pattern Pod	G-7
Power: The East Hall	G-8
Space	G-9
Synopsis: An Introduction	G-10
Talking Points	G-11
The Theatre	G-12
Virtual Voyages	G-13
WW Information/Ticket Desk	G-14

Basement

Eat Drink Shop	B-1
Launch Pad	B-2
The Garden	B-3
The Secret Life of the Home	B-4
The Terrace	B-5
Things	B-6

Need further help finding your way around?



Key

- Information terminal
- Lifts
- Toilets
- Stairs
- Baby changing
- Escalator to IMAX cinema
- Wheel chair access
- Hands on galleries
- Food and drink

List of gallery names

Floor 5

Science and Art of Medicine	5-1
Veterinary History	5-2

Floor 4

Glimpses of Medical History	4-1

Floor 3

Flight	3-1
Flight Lab	3-2
*Flight Picnic Area/Café	3-3
Geophysics and Oceanography	3-4
Health Matters	3-5
Heat and Temperature	3-6
In Future	3-7
Motionride Simulator	3-8
On Air	3-9
Optics	3-10
Photography and Cinematography	3-11
Science in the 18th Century	3-12

Floor 2

Chemical Industry	2-1
Chemistry of Everyday Life	2-2
Computing	2-3
Digitopolis	2-4
Docks and Diving	2-5
Lighting	2-6
Marine Engineering	2-7
Mathematics	2-8
Nuclear Physics and Power	2-9
Picture Gallery	2-10
Printing and Papermaking	2-11
Ships	2-12
Temporary Exhibition Area	2-13
Weighing and Measuring	2-14

Floor 1

Agriculture	1-1
Challenge of Materials	1-2
Food for Thought	1-3
Gas	1-4
Megabite Picnic Area	1-5
Surveying	1-6
Telecommunications	1-7
Temporary Exhibition Area	1-8
Time Measurement	1-9
Weather	1-10
Who am I?	1-11

Ground Floor

Antenna	G-1
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Information Desk	G-4
Making the Modern World	G-5
Museum Café	G-6
Pattern Pod	G-7

What's on?

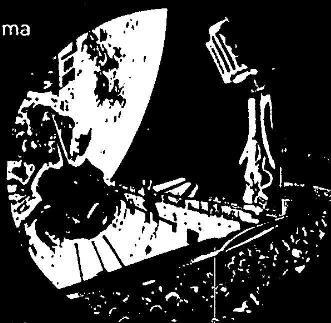
There is a daily programme of visitor events. For full details please contact the Information Desk or use the network of touchscreens available throughout the Museum.

Hands-on galleries for children

During busy times access to these areas may be restricted. Timed ticketing may be in operation. If so, tickets can be collected at the entrance to each gallery.

IMAX* cinema

The 450-seat IMAX cinema shows spectacular 2D and 3D films, accompanied by superb six track stereo sound, on a screen as high as five double-decker buses. To pre-book tickets please contact the Advance Booking Office on 0870 870 4771, or tickets can be purchased from the Box Office in the Museum.



IMAX* is a registered trademark of © Imax Corporation

SimEx Virtual Voyages™

A state-of-the-art motion simulation experience with amazing special effects, digital surround-sound and 70mm projection. This simulator is the first of its kind in Europe. For further information telephone 0870 870 4868.

Height restrictions apply

Museum cafés

The Museum offers a range of catering to suit all needs. The Deep Blue Café in the Wellcome Wing offers hot and cold food served in an open-plan waiter-service restaurant. The Museum Café on the Ground Floor and Eat Drink Shop in the Basement offer hot and cold snacks and drinks.

The Terrace in the Basement and Megabite on the First Floor of the Museum offer areas for visitors to have picnic lunches.

*Flight Picnic Area/Café on the 3rd Floor is open most weekends and holidays.

Gifts and books

The Museum Store and Bookstore stock a wide range of souvenirs, gifts, books and educational toys. A mail order service is also available.
Telephone 020 7942 4499 or buy online at www.sciencemuseumstore.com

Educational groups

Visits to the Museum are free to educational groups at all times if they are booked at least 10 days in advance (subject to daily limit). For information and bookings call the Education Booking Office on 020 7942 4777 or visit our Website: www.sciencemuseum.org.uk/education

Corporate hire

The Museum is also available to hire for Corporate Events. For further information please contact the Events Office on 020 7942 4340/4342 or visit our Website: www.sciencemuseum.org.uk/visitors/corpents

Photography

Any photographs taken must be used for private purposes only and not (unless prior written permission has been obtained) for advertising, trade or business. No tripods or flash equipment can be used in the Museum. Photography is not allowed in the IMAX auditorium. Photographs of pictures or objects in the Museum maybe obtained from the Science & Society Picture Library. Telephone 020 7942 4400 or visit our Website: www.sciencemuseum.org.uk/piclib

Bookings

For general bookings contact **0870 870 4868.**

Opening hours

Daily 10:00 – 18:00 Closed 24, 25, 26 December

Facilities for visitors with disabilities

We endeavour to cater for visitors with special needs and all our events are carefully selected to appeal to different audiences. An 'Access and Facilities guide' is available in advance or from the Information Desk on arrival. Minicom Line 020 7942 4445.
Information Line 020 7942 4446

First aid

Please contact any member of staff for assistance.

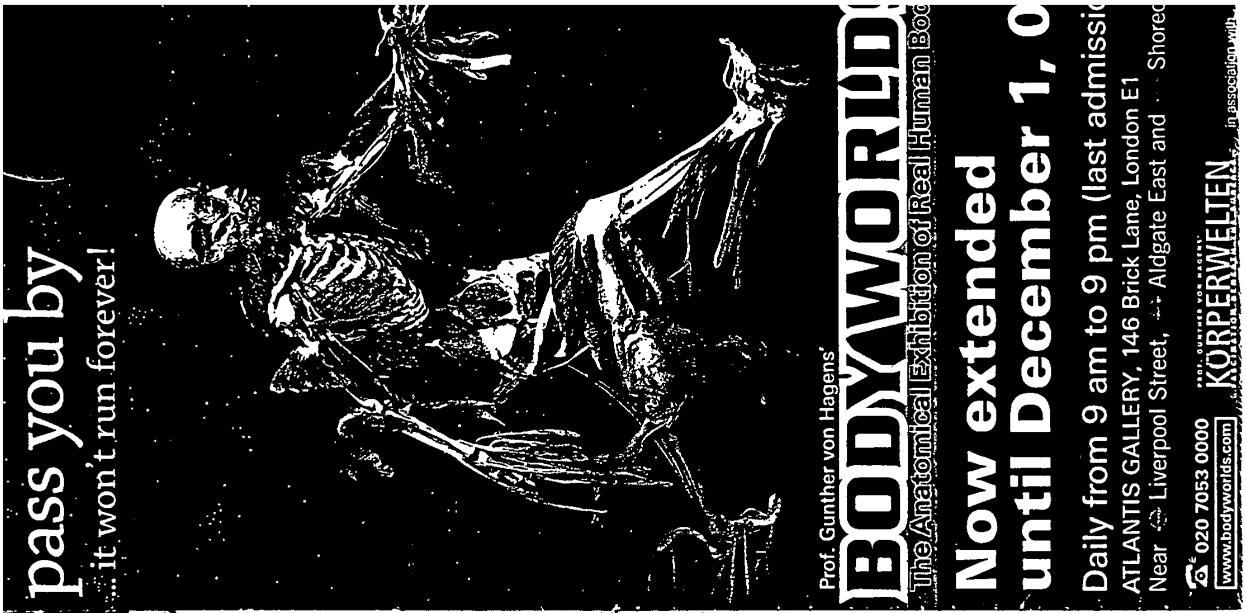
Science Museum Library

The National Library for the History and Public Understanding of Science and Technology is 300 metres from the Museum on Imperial College campus and is open to the public. Telephone 020 7942 4242 or visit our Website: www.sciencemuseum.org.uk/library

Charter Mark

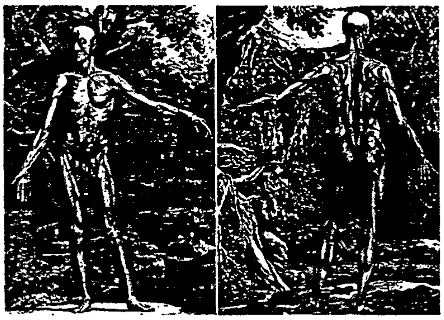
The Museum has been awarded a Charter Mark for its standard of customer service. If you have any comments about your visit, please speak to a member of staff or complete one of our Customer Comments forms available at the Information Desk.

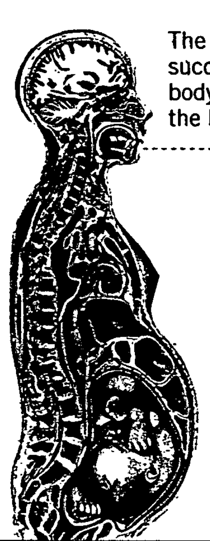
Science Museum
Exhibition Road, London SW7 2DD
E-mail us at sciencemuseum@nmsi.ac.uk
Visit our Website at www.sciencemuseum.org.uk



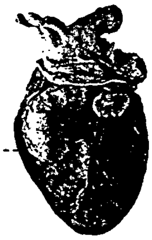
…e anatomist, **André** who revolutionised …ge of the interior human body and considered the … of scientific ana-

Bernard Albinus demonstrated the totality of the biological system such as the brain in connection with the meninges and the nerves, which allowed, in turn a better understanding of how the organs function.





The Russian anatomist, **Pirogoff** succeeded in slicing through the body, to offer a complete view of the body's interior.



Owing to the plastination process, the body can now be revealed in three dimensions.

… century	17th-18th century	19th century	Today

… Liverpool Street

…tral / Circle / District / Hammer…th and City / Metropolitan 1st …at Eastern / Anglia no. 8,11,23, …35,42,47,48,78,133,149,15… …14,242, Walking: 7 mins

… Aldgate East

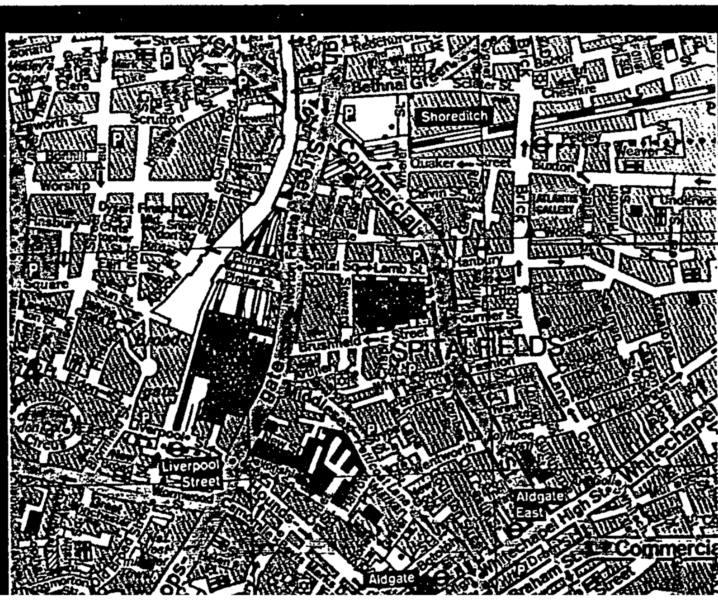
…trict / Hammersmith and City …25,67,253, Walking: 5 mins

… Shoreditch

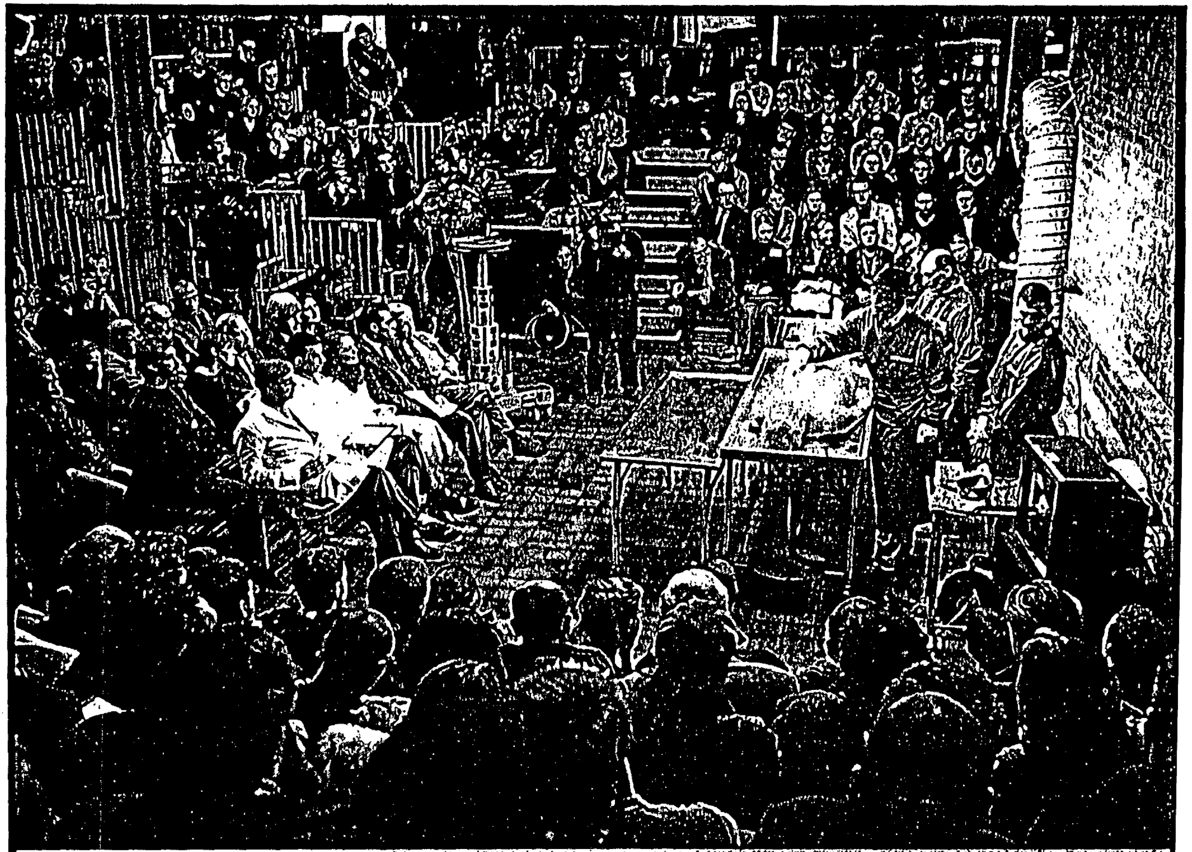
…t London Line (Mon to Fri 7am-…m & 3pm-7pm / Closed Sat / … 7am-3pm) no.8 from Bethnal …en Road, Walk: 1 min

…rking

…ase use public transport since



Atlantis Gallery
146 Brick Lane
London E1

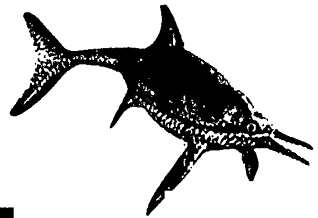


■德國醫生哈根斯（右）廿日在倫敦舉行美國一百七十年來首次公開人體解剖，當地電視台現場直播全程報導。（路透）

maden/Teck am Fuße der Schwäbischen Alb ist weltbekannt als Fundgebiet für Fossilien aus den Posidonienschiefern – Meeresablagerungen, die vor 180 Millionen Jahren am Grund des Jurameeres entstanden sind.

Im Urwelt-Museum Hauff sind auf 1000 m² Ausstellungsfläche mehr als 400 Präparate aus diesen Schichten zu besichtigen. Es ist das größte private Naturkundemuseum Deutschlands.

Die Sammlung umfaßt Ichthyosaurier, Plesiosaurier, Krokodile, Flugsaurier, Fische und zahlreiche wirbellose Tiere. Zu den bekanntesten Ausstellungsstücken gehört ein fast 4 m langes Ichthyosaurier-Muttertier mit einem bereits geborenen Jungen und fünf Embryonen im Leib.



Besonders eindrucksvoll ist die über 100 m² große Kolonie von Seelilien. Sie ist das weltweit größte Exemplar, das bisher gefunden und präpariert wurde.

Mit einem naturgetreuen Nachbau der Schichtabfolge der Posidonienschiefer werden die Entstehungsgeschichte der einzelnen Schichten, sowie die jeweils typischen Fossilien gezeigt.

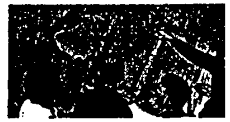
Dreidimensionale Schaubilder und Modelle von Sauriern geben Aufschluss über das Leben im Jurameer, ihre Fossilisation, das Finden im Schieferbruch und die Präparation in der Werkstatt.

Im Museum können Originalversteinerungen in verschiedenen Größen und Preisklassen käuflich erworben werden.

Das Urwelt-Museum Hauff wird als Stiftung verwaltet. Es ist im täglichen Betrieb und zur weiteren Ausgestaltung auf Spenden angewiesen.

Spendenkonto:
Deutsche Bank AG Göppingen
Konto Nr. 031 1001 BLZ 610 700 78

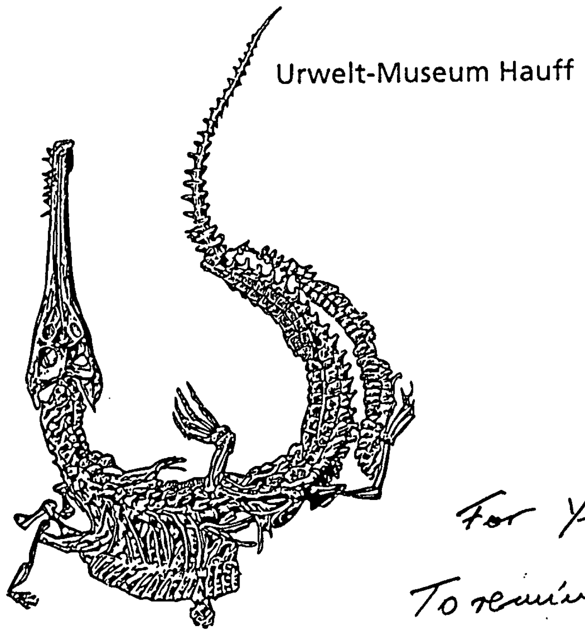
Gruppe ab 20 Personen	1,00
Schwerbehinderte	3,00
Gruppen/Schulklassen bitte unbedingt anmelden.	



Im Museum erhältlich:

Museumsführer	3,00
Museumsquiz	3,00
Im Versand	5,00
Bezahlung bitte in Briefmarken	
Museumskatalog	9,00
Im Versand	11,00
Holzmadenbuch	
137 Seiten mit	
188 Abbildungen	30,00
Im Versand	35,00
Bezahlung bitte mit Scheck	
Lehrfilm „Lebendige Urwelt"	
(ca. 20 Minuten)	
Filmvorführung im Museum	12,00
Persönliche Führungen (ca. 3/4 Stunde)	
Wir bitten 14 Tage vorher um Anmeldung	
deutsch	45,00
englisch	65,00
Dinosaurier-Ausgrabungsfeld	
Buchung	15,00

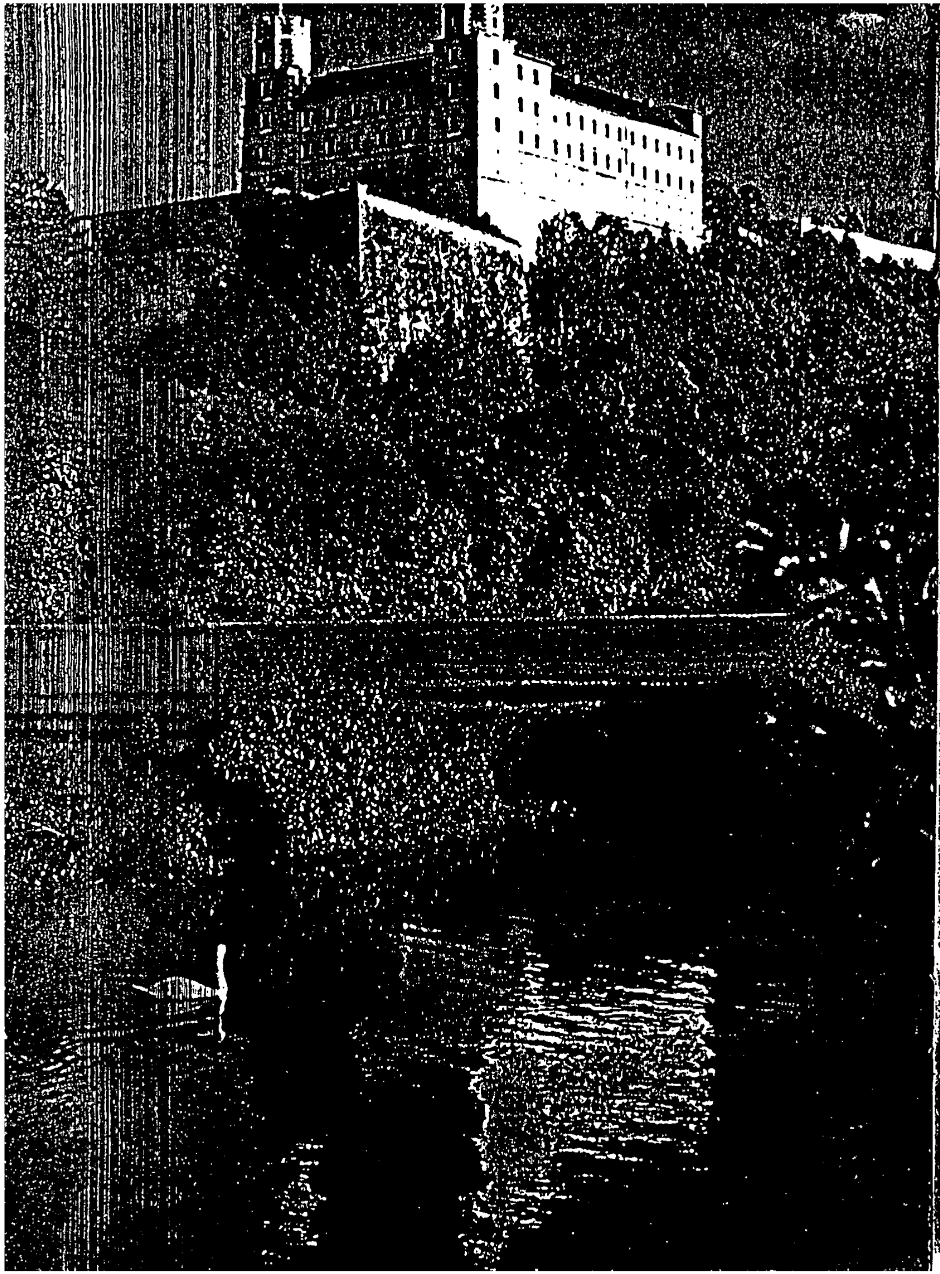
Petit guide
Guida breve



2002年10月28日
造訪Holzmaden博物館
"(Urwelt-Museum Hauff)。
私人博物館，館長
贈我這本冊子。
精彩設計，超出想像！

For You-wien Cheng
To remind your visit
in Holzmaden
Holzmaden 28.10.2002
Rolf Hauff

(Bernhard Hauff
Rolf Bernhard Hauff)

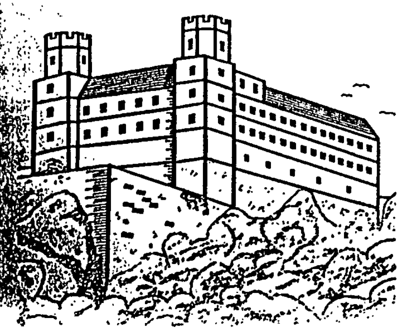


Jura-Museum Eichstätt Willibaldsburg

The fossils of the Solnhofen Lithographic Limestone

Les fossiles du calcaire lithographique de Solnhofen

I fossili del Calcare Litografico di Solnhofen

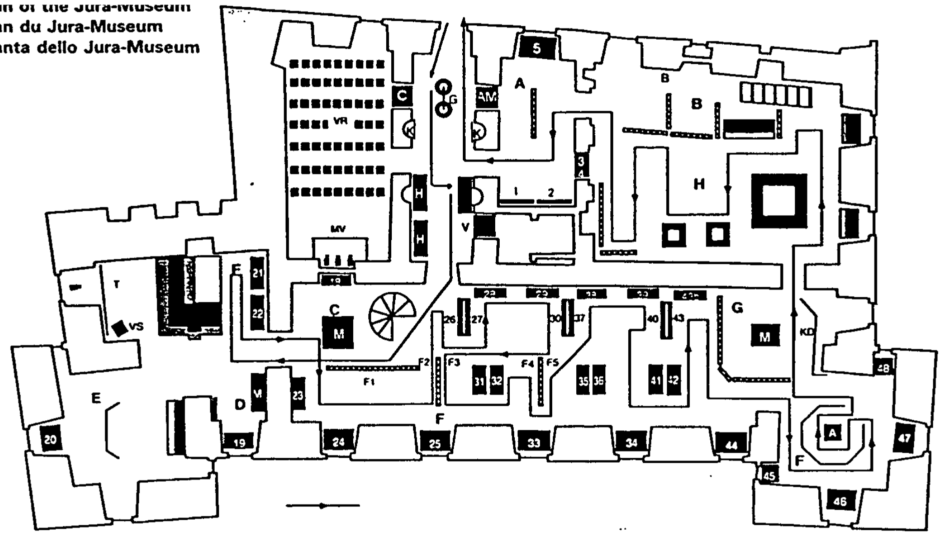


Brief guide

Petit guide

Guida breve

Plan of the Jura-Museum
Plan du Jura-Museum
Pianta dello Jura-Museum

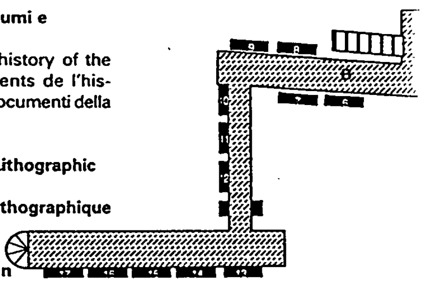


A *Archaeopteryx*
AM Model of *Archaeopteryx* / Reconstitution d'*Archaeopteryx* / Modello dell'*Archaeopteryx*
B Eichstätt bore hole
Sondage d'Eichstätt
Sondaggio di Eichstätt
C Model of *Compsognathus* / Reconstitution de *Compsognathus* / Modello di *Compsognathus*
G Globes / Globes terrestres / Globi
H Cherts / Silex / Selci
K Silicified wood / Du bois silicifié / Legno silificato
KD Small dioramas / Petits dioramas / Piccoli diorami
M Model / Maquette / Plastico

inférieur (Buntsandstein) / Permiano e Triassico inferiore (Buntsandstein)
8 Middle Triassic (Muschelkalk)
Trias moyen (Muschelkalk)
Triassico medio (Muschelkalk)
9 Upper Triassic (Keuper) / Trias supérieur (Keuper) / Triassico superiore (Keuper)
10 Lower Jurassic (terrestrial and littoral deposits) / Jurassique inférieur (dépôts terrestres et littorals) / Giurassico inferiore (depositi terrestri e littorali)
11 Lower Jurassic / Jurassique inférieur / Giurassico Inferiore
12 Lower Jurassic / Jurassique inférieur / Giurassico inferiore

Section E: History of the Rivers and the Landscape
Section E: L'histoire des rivières et des paysages
Sezione E: Storia dei fiumi e del paesaggio
20 Documents of the history of the rivers / Des documents de l'histoire des rivières / Documenti della storia dei fiumi

Section F: Solnhofen Lithographic Limestone
Section F: Le calcaire lithographique de Solnhofen
Sezione F: Calcare Litografico di Solnhofen



31 Crustaceans / Les crustacés / Crostacei
F3 Giant fish / Des poissons géants / Pesci giganteschi
32 Crustaceans / Les crustacés / Crostacei
F4 Giant fish / Des poissons géants / Pesci giganteschi
33 Insects / Les insectes / Insetti
34 Bivalves, gastropods, ammonites / Les bivalves, gastéropodes et ammonites / Lamellibranchi, Gasteropodi ed Ammoniti
35 Belemnites, sqids, and cuttlefish / Les belemnites, seiches et calmars / Belemniti e calamari
F5 Sqids, cuttlefish, and ammonites / Les seiches, calmars et ammonites / Calamari e ammoniti
36 Echinoderms / Les échinodermes / Echinodermi
37 Cartilaginous fish / Les poissons cartilagineux / Condroitti
38 Crossopterygians (lobefinned fish) / Les crossoptérygiens (poissons à nageoires charnues) / Crossopterigi

MV Multi-image display
Présentation multivisuelle
Proiezione multivisionale
T Audio-visual display
Présentation audio-visuelle
Audiovisivo
V Evolution of mesozoic birds / Évolution des oiseaux mésozoïques / Evoluzione degli uccelli mesozoici
VS Video display / Films vidéo / Video

Section A: General Palaeontology
Section A: La paléontologie générale
Sezione A: Paleontologia generale
1 Fossil preservation of soft parts / Conservation fossile des parties molles / Conservazione fossile delle parti molli
2 Fossil preservation of shells
Conservation fossile des tests
Conservazione fossile dei gusci
3 Ammonites / Les ammonites / Ammoniti
4 Belemnites / Les bélemnites / Belemniti
5 Brachiopods and sponges
Les brachiopodes et éponges
Brachiopodi e spugne

Section B: Geology of Northern Bavaria
Section B: La géologie du Nord de la Bavière
Sezione B: Geologia della Baviera Settentrionale
6 [illegible] basement) / Soubassement hercynien / Basamento [illegible]
7 Permian and Lower Triassic (Buntsandstein) / Permien et Trias

férieur / Giurassico inferiore
13 Lower and Middle Jurassic
Jurassique inférieur et moyen
Giurassico inferiore e medio
14 Upper Jurassic / Jurassique supérieur / Giurassico superiore
15 Upper Jurassic / Jurassique supérieur / Giurassico superiore
16 Upper Jurassic / Jurassique supérieur / Giurassico superiore
17 Cretaceous and Tertiary / Crétacé et Tertiaire / Cretaceo e Terziario

Section C: The Meteorite Crater "Nördlinger Ries"
Section C: Le Cratère météoritique de «Nördlinger Ries»
Sezione C: Il Cratere meteoritico »Nördlinger Ries«
18 Documents of the impact
Des documents de l'impact
Documenti dell'impatto

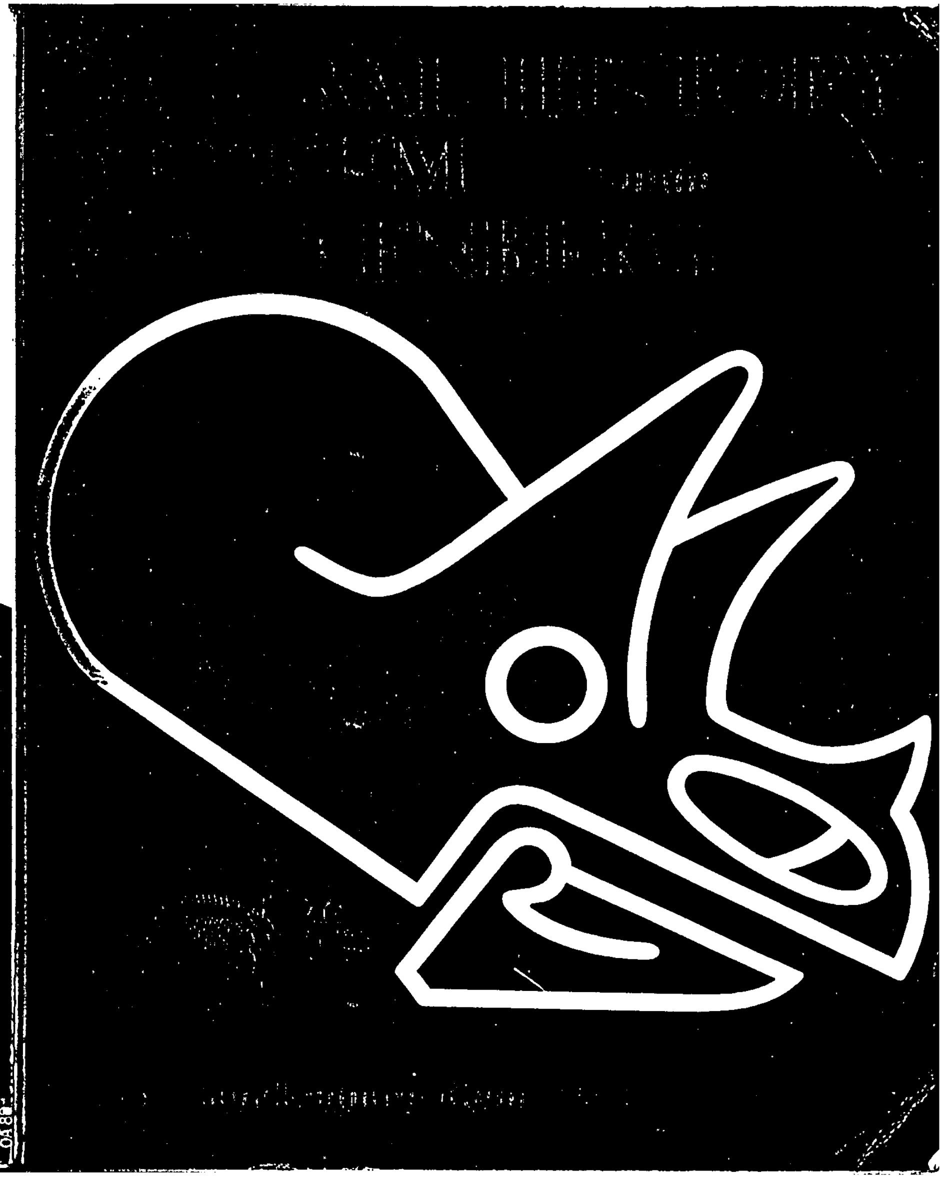
Section D: Karstification and Groundwater
Section D: Les phénomènes karstiques et les eaux souterraines
Sezione D: Carsismo e l'acqua freatica
19 Small karst phenomena (solution and precipitation of calcium carbonate) / Des petits phénomènes karstiques (solution et précipitation de carbonate de calcium) / Piccoli fenomeni carsici (soluzione e precipitazione di carbonato di calcio) [illegible]

21 The coral patch reefs / Les petits récifs coralliens / Le piccole scogliere coralline
22 The preservation of fossils in the basins of the Solnhofen Lithographic Limestone / La conservation des fossiles dans les bassins du calcaire lithographique de Solnhofen / La conservazione dei fossili nei bacini del Calcare Litografico di Solnhofen
23 Embedding of the fossils / L'enfouissement des fossiles / Il seppellimento dei fossili
F1 Current indicators / Des témoins de courants marins / Indicazioni di correnti
24 Traces of life / Des traces d'activité organique / Tracce di vita
F2 Tracks and other things / Des pistes et d'autres choses / Orme ed altre cose
25 Predation / Prédation / Predazione
26 Pigmentation of the Solnhofen Lithographic Limestone / Pigmentation du calcaire lithographique de Solnhofen / Pigmentazione del Calcare Litografico di Solnhofen
27 Water plants (seaweeds) / Les plantes aquatiques (algues marines) / Piante acquatiche (fuchi)
28 Land plants / Les plantes terrestres / Piante terrestri
29 Sponges, jellyfish, gorgonians, and annelid worms / Les éponges, méduses, gorgones et annélides / Spugne, meduse, gorgonie e Anellidi (vermi)
30 Horseshoe crabs and Crustaceans / Les limules et crustacés / Limuli e Crostacei

39 "Holosteans" ("bony ganoid fish") / Les «holostéens» («poissons osseux ganoides») / »Olostei« (»pesci ganoidei ossei«)
40 "Holosteans" / Les «holostéens» / »Olostei«
41 "Chondrosteans" ("cartilaginous ganoid fish") / Les «chondrostéens» (poissons cartilagineux ganoides) / »Condrostei« (»pesci ganoidei cartilaginei«)
42 Teleosts (modern bony fishes / Les Téléostéens (poissons osseux modernes) / Teleostei (i moderni Osteitti)
43 "Holosteans" / Les «holostéens» / »Olostei«
43b Reptiles (crocodiles, *Pleurosaurus*) / Les reptiles (des crocodiles, *Pleurosaurus*) / Rettili (coccodrilli, *Pleurosaurus*)
44 Reptiles (rhynchocephalians, lizards) / Les reptiles (rhynchocephales, lézards) / Rettili (Rincocefali, lucertole)
45 Reptiles (turtles) / Les reptiles (tortues) / Rettili (tartarughe)
46 Reptiles (pterosaurs) / Les reptiles (ptérosaures) / Rettili (Pterosauri)
47 Reptiles (pterosaurs) / Les reptiles (ptérosaures) / Rettili (Pterosauri)
48 Reptiles (pterosaurs) / Les reptiles (ptérosaures) / Rettili (Pterosauri)

Section G: The Altmühl Valley as Habitat today
Section G: La vallée d'Altmühl dans l'habitat contemporain
Sezione G: La valle dell'Altmühl oggi

Section H: The Aquaria
Section H: La salle des aquariums
Sezione H: La sala degli acquari



ıf der Route VIA RAETICA begibt sich der Interessierte sucher auf die Spuren der Römer von Donauwörth bis gensburg. Wo einst römische Legionäre marschierten, nnen Reisende heute Geschichte „erfahren". hlreiche Angebote begleiten die abwechslungsreiche urensuche entlang der ehemaligen Römerstraßen ıetiens und machen die Reise zu einem einmaligen ebnis.

Naturpark Altmühltal bieten das **Jura-Museum** :hstätt, das **Römer und Bajuwaren Museum** in ɔfenberg und das **Museum für Ur- und Frühgeschichte** :hstätt in Zusammenarbeit mit dem **Informations- und nweltzentrum Eichstätt** interessante Exkursionen an. Wir ıben ein abwechslungsreiches Programm zusammen- ɔstellt. Schleicht mit uns doch einmal auf den Spuren ın **urzeitlichen Tieren**, wandelt auf den Wegen der ömer, und entdeckt die lebendigen **Naturschönheiten** ɔs Altmühltals.

Die Exkursionen sind für kleine und große Gruppen (max. 30 Personen) jeden Alters gedacht. Sie eignen sich sehr gut für einen **Familienausflug**, sind aber auch eine ideale Ergänzung zum **Biologie-**, **Geographie-** oder **Geschichtsunterricht** (Arbeitsblätter für verschiedene Klassenstufen und zu einzelnen Themen gibt es auch bei uns).

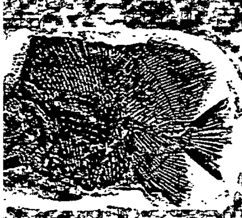
Spaß und **Action** sind dabei garantiert. Speziell für Kinder sind beispielsweise unsere **Kanu-Touren** gedacht. So richtig Hand anlegen könnt Ihr bei einer **Fossiliensuche** im Steinbruch. (Unsere Begleiter zeigen Euch, wie man wirklich welche findet).

Ihr könnt Euch natürlich auch einzelne Programmpunkte selbst zusammenstellen. Dabei sind wir gern behilflich.

Zur **Buchung**: Siehe Rückseite.

ıntauchen in das Jurameer ①

das Jura-Museum und seine umgebende Landschaft



- Führung durch das Jura-Museum
- Wanderung (ca. 1 Stunde) mit Erklärung der Landschaftsgeschichte
- Fossiliensuche im Steinbruch

Dauer: ca. 4 Stunden
April bis Oktober
für alle Altersgruppen

- Fußwanderung

Treffpunkt: Jura-Museum

rüher sah es hier ganz anders aus ... ②

ıtstehung von Oberflächenformen

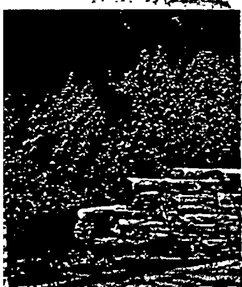
Das Wellheimer Trockental
Urmain und Urdonau
Landschaftsentwicklung der Franken- und Altmühlalb (im Gelände)

Dauer: 4 bzw. 8 Stunden
Anfahrt: mit Bus oder Fahrrad
April bis Oktober
für alle Altersgruppen

Treffpunkt: Jura-Museum

/o das Trinkwasser knapp wird ③

er natürliche Wasserkreislauf und spezielle Probleme im Karst der Frankenalb



+ Die Karstlandschaft der Frankenalb (Ton-Bild-Schau im Jura-Museum)
+ Diskussion zum Thema „Probleme der Trinkwasserversorgung"
+ Geologische Wanderung von Obereichstätt zum Steinbruch
+ mit Fossiliensammeln mit Betrachtung von Karstformen, Steinbrüchen und Bauschuttdeponien
+ Landschaftsentwicklung vom Talgrund des Altmühltales bis zur Albhochfläche
+ Fossiliensuche im Steinbruch

Dauer: 4-5 Stunden
Anfahrt: mit Bus oder Fahrrad
April bis Oktober
für alle Altersgruppen

Treffpunkt: Jura-Museum

/asser ist Lebensraum ④

nblick in das vielfältige Leben in und an einem ɪewässer

Wirbeltiere verschiedener Lebensräume
Lurche

Dauer: mind. 2 Stunden
März/April bis Frühsommer
für alle Altersgruppen

- Fußwanderung

Treffpunkt: Jura-Museum

+ Die Karstlandschaft der Frankenalb (Ton-Bild-Schau im Jura-Museum)
+ Diskussion zum Thema „Probleme der Trinkwasserversorgung"
+ Geologische Wanderung von Obereichstätt zum Steinbruch für Fossiliensammler mit Betrachtung von Karstformen, Steinbrüchen und Bauschuttdeponien
+ Landschaftsentwicklung vom Talgrund des Altmühltales bis zur Albhochfläche
+ Fossiliensuche im Steinbruch

Dauer: 4 - 5 Stunden
Anfahrt: mit Bus oder Fahrrad
April bis Oktober
für alle Altersgruppen

Treffpunkt: Jura-Museum

/asser ist Lebensraum ④

nblick in das vielfältige Leben in und an einem ·ewässer

Wirbeltiere verschiedener Lebensräume
Lurche

Dauer: mind. 2 Stunden
März/April bis Frühsommer
für alle Altersgruppen

- Fußwanderung

Treffpunkt: Jura-Museum

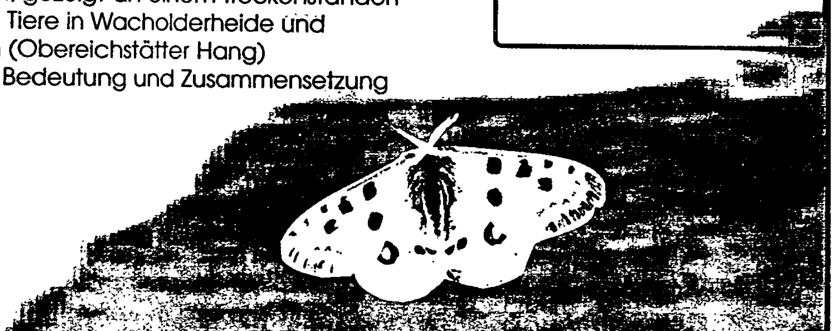
n Einklang mit der Natur ⑤

aturbeobachtungen in Trockenrasen und Wachholderheide

+ Vielfalt und Schönheit einheimischer Samenpflanzen
+ Anpassung an besondere Lebensbedingungen
+ Einfache Zusammenhänge einer Lebensgemeinschaft, gezeigt an einem Trockenstandort
+ Pflanzen und Tiere in Wacholderheide und Trockenrasen (Obereichstätter Hang)
+ Ökologische Bedeutung und Zusammensetzung der Hecken

Dauer: ca. 3 Stunden
April bis Oktober
für alle Altersgruppen

Treffpunkt: Obereichstätt



lit dem Kanu auf Fossiliensuche ⑥

ı aufregendes Ferienabenteuer mit vielen Überraschungen ...

+ Höhlenbesichtigung
+ Kanutour nach Obereichstätt
+ Geologischer Lehrpfad ins Steinbruchgebiet
+ Fossiliensuche
+ Besuch im Jura-Museum (mit Führung)

Treffpunkt: 9:30 Uhr Breitenfurt
Ende: Jura-Museum (ca. 17 Uhr)

›itreise mit dem Kanu ⑦

›n der Urzeit bis zu den Römern — Ein spannendes Ferienerlebnis

Besuch im Jura-Museum (mit Führung)
Kleine Wanderung über den Frauenberg
Kanutour bis Walting mit Zwischenstop an einer Karstquelle und im Römerkastell Pfünz
Besuch im historischen Zehnthof in Walting (mit Führung)

Treffpunkt: 9:30 Uhr Jura-Museum
Ende: Zehnthof Walting (ca. 16 Uhr)

Ferien-Special !
Ganztägige Kinderbetreuung

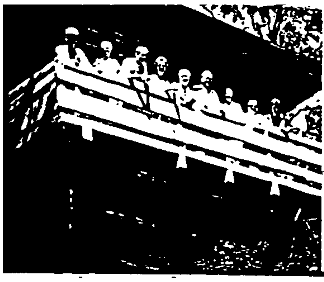
Dauer: ca. 7 - 8 Stunden

Termine: (für Tour 6 und 7) nach Vereinbarung

Alter: 10 bis 15 Jahre
Ab 8 Personen

Kosten: 29,- €
pro Person incl. Kanu, Schwimmweste und Museumsführung

Nicht vergessen! Picknick, wetterfeste und bequeme, strapazierfähige Kleidung und festes Schuhwerk, Sonnen- bzw. Regenschutz



Führung durch das Römer und Bajuwaren Museum – Wanderung entlang der sichtbaren Spuren des Limes bis Böhming (ca. 5 km; gutes Schuhwerk erforderlich!)
- Alltag eines römischen Grenzsoldaten

Zusätzliche museumspäd. Angebote und Programmerweiterung nach Absprache

Tipp: Einkehr im Gasthof Römer Castell / Böhming mit original römischen Speisen!

für alle Altersgruppen
- Fußwanderung

Treffpunkt: Kipfenberg

Kosten: 80 € (bis 20 Personen jede weitere Person 2,50 € 55 € für Schulklassen; incl. Museumseintritt und Führung

·ührungen im Römerkastell Pfünz

listorischer Verein Eichstätt

⑨

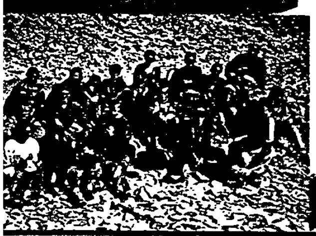
- Baugeschichte des Kastells
- römische Militärgeschichte
- römisches Leben
- Limesgeschichte

Dauer: nach Absprache
- ganzjährig
- für alle Altersgruppen
- Fußwanderung

Treffpunkt: Pfünz

rojekt-Paket zum Selberschnüren

ndividuelle Gestaltung von einem oder mehreren Tagen



Selbstverständlich könnt Ihr auch einzelne Programmpunkte der verschiedenen Exkursionen kombinieren. Wir beraten Sie gern bei der Zusammenstellung eines abwechsungsreichen Programmes über einen oder mehrere Tage. Sehr beliebt sind **Projektwochen** für Schulkassen.
Daneben bietet der Naturpark Altmühltal viele Aktivitäten und Sehenswürdigkeiten, die das Programm abrunden. (Informationen: Naturpark Altmühltal Tel. 08421/9876-0)

Vas ist die Via Raetica?

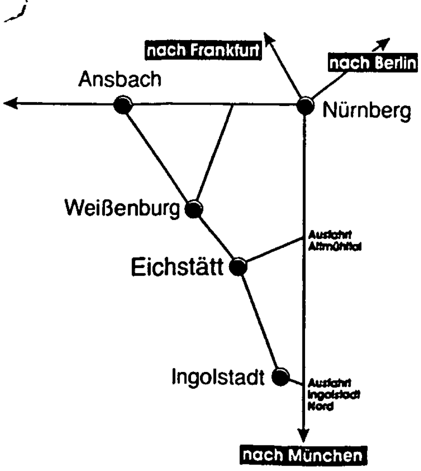
Römische Spuren im Naturpark Altmühltal

ie VIA RAETICA mit ihrem dichten Netz von **2000 Jahre** alten römischen Verkehrswegen führt Euch auf insgesamt 80 km Länge an Zeitzeugen, historischen Denkmälern und modernen Museen zurück zu den römischen Wurzeln iner ursprünglichen Landschaft. Neben der faszinierenden Natur bieten die Museen des **Museumsverbundes VIA AETICA** einen eindrucksvollen Einblick in Themen wie Landwirtschaft, Verkehr, Militär und Baukultur. Die zeitliche andbreite der Museen reicht von der Jurazeit über die Römer bis heute. Die **gastliche Vielfalt** der bayerischen atur- und Kulturlandschaft zwischen Donauwörth und Regensburg verwöhnt Sie in der Gegenwart!
ne **neu erschienene Radwanderkarte** der VIA RAETICA gibt zahlreiche Anregungen und eine große Auswahl an hemen zur Ergänzung für eine Exkursion. Sie ist beim Naturpark Altmühltal und in den Museen für 1 € erhältlich.

Vas Sie sonst noch wissen sollten ...

nreise und Ablauf: ❺❻

ür die Anfahrt bietet sich die **Bahn** n, vom Bahnhof Eichstätt Stadt (!) bis um Jura-Museum läuft man nur 15 linuten; die **Jugendherberge** liegt auf alber Strecke.
ür unsere Exkursionen nutzen wir so eit als möglich und gewünscht **ffentliche Verkehrsmittel** und **ahrräder** oder gehen zu **Fuß**. Bei zwei kursionen sind wir sogar mit dem **anu** auf der Altmühl unterwegs.
Venn Sie als größere Gruppe anreien, empfiehlt es sich, einen **Reisebus** ir einen (halben) Tag zu chartern. dressen von Busunternehmen vor Ort eilen wir gern mit.



Wichtiger Hinweis:

Nicht vergessen: Wetterfeste Kleidung, feste Schuhe, ggf. Gummistiefel, Hammer und Meißel

Impressum
Herausgeber: Jura-Museum Eichstätt
Text und Layout:
Marlen Schlaffke / Hans-Dieter Haas
© 2001
Druck: Brönner & Daentler, Eichstätt

Die Herstellung des Prospektes wurde mit LEADER II-Fördermitteln der Europäischen Union ermöglicht

1.10.–31.3.: 10.00–16.00

Montags sowie am 1.1., Faschingsdienstag, 1.11., 24.12., 25.12. und 31.12. geschlossen.

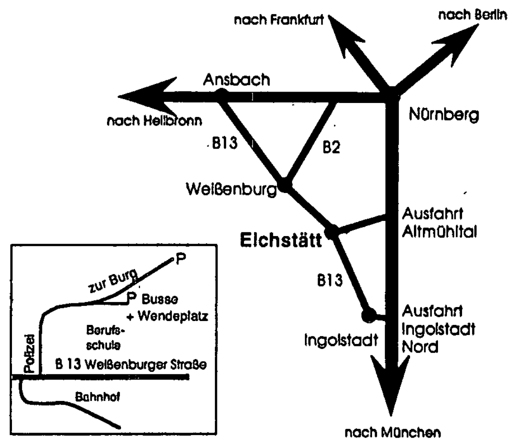
Multivisionsschau/Multi-image display/
Présentation multivisuelle/Proiezione multivisionale:

10.15 und/and/et/e 15.00
In Ausnahmefällen auch außerhalb der festgesetzten Zeiten.
Special showings by arrangement.
En cas exceptionnels également en dehors des heures fixes.
In casi eccezionali anche oltre gli orari stabiliti.

Museumsführungen, Steinbruchsführungen und landschaftskundliche Exkursionen nach Voranmeldung.
For guided tours of the museum and a quarry advance booking is requested.
Des visites guidées du Musée et des excursions à une carrière ne sont possibles qu'après préavis.
Visite guidate nel museo e escursioni in una cava sono possibili solo su appuntamento.

Anschrift/Address/Adresse/Indirizzo:

Jura-Museum
Burgstr. 19
D-85072 Eichstätt
Tel.: 08421/2956 (Sekretariat)
08421/4730 (Kasse und Burgverwaltung)
Fax: 08421/89609
E-Mail: Sekretariat@jura-museum.de
http://www.jura-museum.de



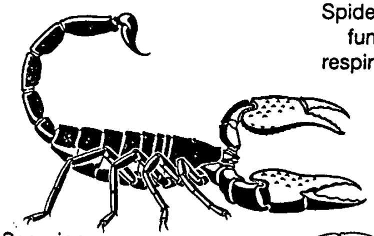
Herausgeber: Jura-Museum, Bischöfliches Seminar Eichstätt
Gesamtherstellung: Verlag Dr. Friedrich Pfeil, München

Le Jura-Museum a pour base les riches collections d'histoire na-

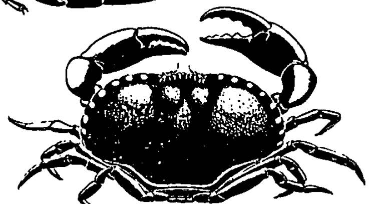
ther themes of the exhibition are the formation of fossils, im-

Insects Room 203
Spiders and crustaceans Room 204

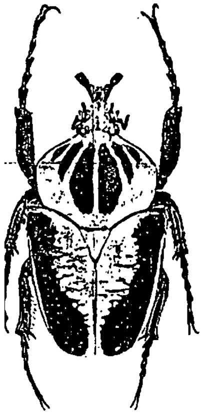
Spiders and crustaceans fundamentally differ in respiration, anatomy and the number of extremity pairs (Chelicerata 4, crustaceans 5).

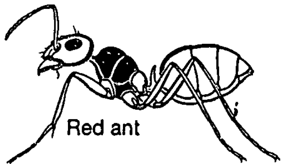


Scorpion

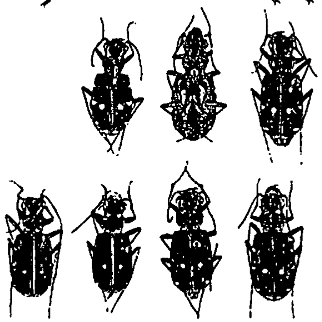


Common crab

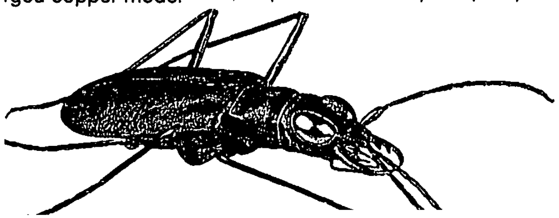




Red ant

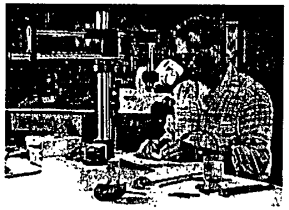


ant beetle (*Goliathus*);
er beetles and an
rged copper model



The Research Institute of the Senckenberg Nature Research Society

Behind the scenes at the museum:
Only a fraction of the collection is accessible to visitors. All other objects, carefully labeled and systematically organized, are available to scientists. Like documents in archives, they are evidence of the development and the diversity of life on earth.



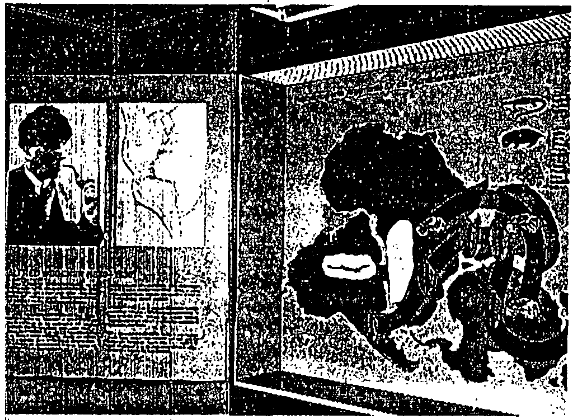
The scientific laboratories analyze, prepare and work on fossils as well as on modern animals and plants.
The results of this research work are published in scientific journals.
The Natural History Museum and Research Institute act as a center for biodiversity research and aim to describe, understand, and protect the diversity of life. Priorities of research are systematics, which means the arrangement of organisms within systematic categories, as well as ecology,

Senckenberg Natural History Museum and Research Institute

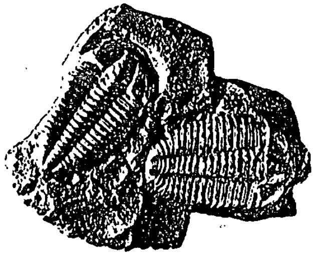
Center for biodiversity research

Senckenberg Nature Research

Planets, plate tectonics, volcanism, and historical geology Room 14-15



sy-to-understand models ow the construction of th, Alfred Wegener's itinental drift theory and structure of our solar tem.



Two fossilized trilobites

irge mural of the olutionary cycle of rocks.

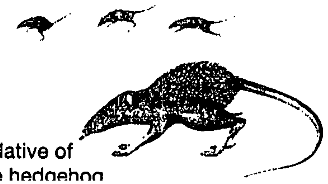
Fossils from the Messel Mine Room 16

In 1992 the Senckenberg Nature Research Society was commissioned to coordinate the excavation activities of various scientific institutions at the Messel mine. In December 1995 the Messel mine was the first German site nominated by UNESCO to be included in the list of World Heritage Sites.

Prehistoric ungulate *Kopidodon*

The most famous finds, such as the "prehistoric horse", can be seen here.

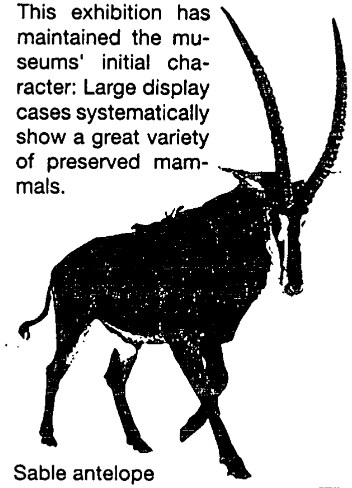
Leaf of a walnut plant



Relative of the hedgehog

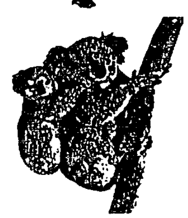
Mammals Room 101-102

This exhibition has maintained the museums' initial character: Large display cases systematically show a great variety of preserved mammals.



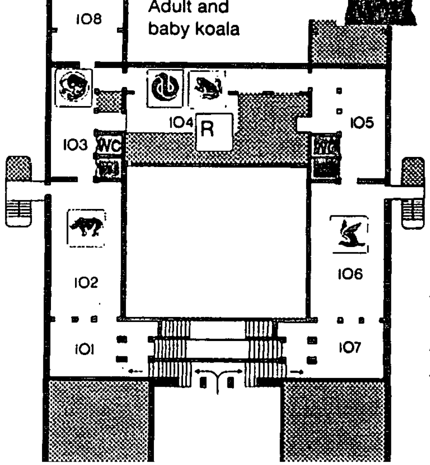
Sable antelope

Okapi family



Adult and baby koala

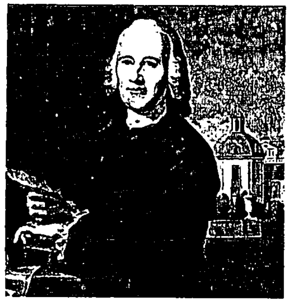
Male gorilla



First floor
101,102 Mamma
103 Giants and dwarfs amo plants and animals; Embryos
104 Amphibians and reptiles
105-107 Birds
108 Evolution of the plant kingdom
R Restroom

ʜistory oɪ the Ꮪenckenberg Nature Research Society Room 3

ıe Senckenberg Nature
esearch Society (SNG) in
ʼankfurt am Main was
ımed in memory of
r. Johann Christian Sen-
ꞔenberg, a local physi-
an and patron who had
ished to establish an
lucational institution for
ıtural sciences. However,
was not until 1815 that
s idea was proposed
jain by Johann Wolfgang
ın Goethe. He supported
ıdeavors to bring toge-
er existing scientific
ıllections under the aus-
ces of the Nature Re-
ʼarch Society and so
ake them available to
ientific research. Goethe
tiated the establishment
a "Natural History
ɹseum" and scientific
rary. In answer to his
ʼpeal, the Senckenberg
ıture Research Society
ıs founded in 1817 by
ıillipp Jakob Cretzsch-
ar, who brought together
terested Frankfurt
tizens of various
ıckgrounds.

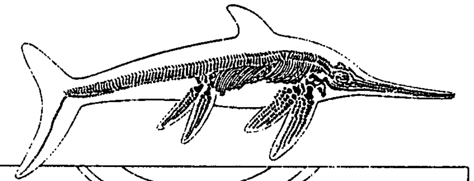


Johann Christian Senckenberg
1707-1772 Frankfurt physician and patron, gave name to the Nature Research Society

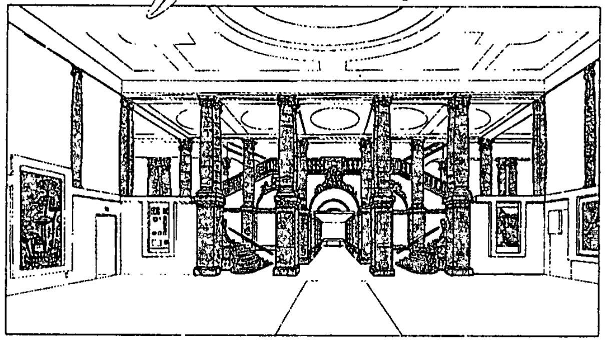
Johann Wolfgang v. Goethe
1749-1832 Poet and natural scientist, appeals to Frankfurt's citizens

Phillip Jakob Cretzschmar
1786-1845 the founder of the Society

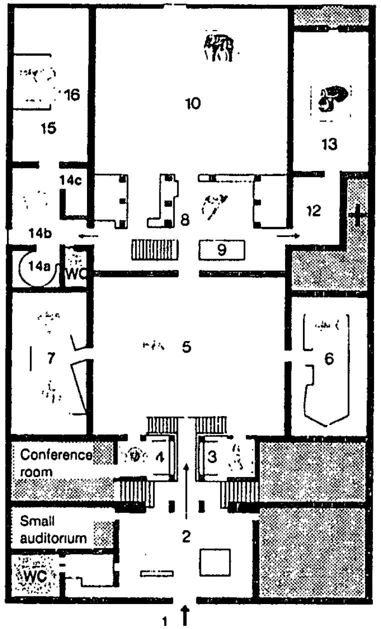
Entrance hall and staircase Room 2



Ichthyosaur



Architecture of the museum by LUDWIG NEHER

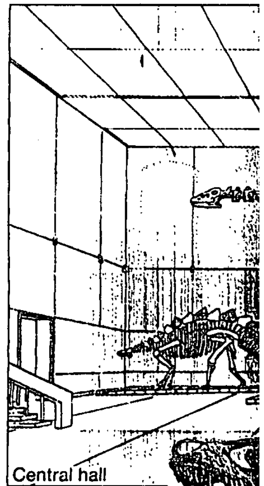


Ground floor halls

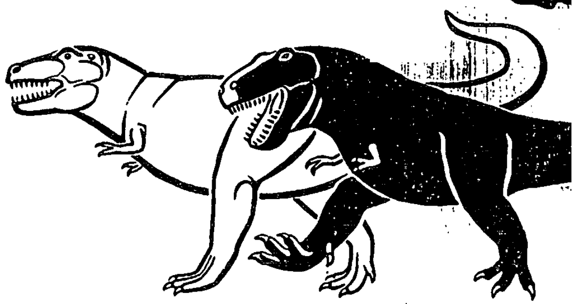
1 Front garden
2 Entrance hall
3 SNG history
4 Egyptian mummies
5 Dinosaurs
6 Fossilized aquatic vertebrates
7 Minerals and invertebrate animals
8 Fossil mammals
9 *Edmontosaurus*
10 Whales and elephants
12, 13 Origin of man
14a Our solar system
14b Plate tectonics
14c Earthquakes
15 History of earth and life
16 Fossils from the Messel mine
\+ Mother/infant room (ask attendant for key)

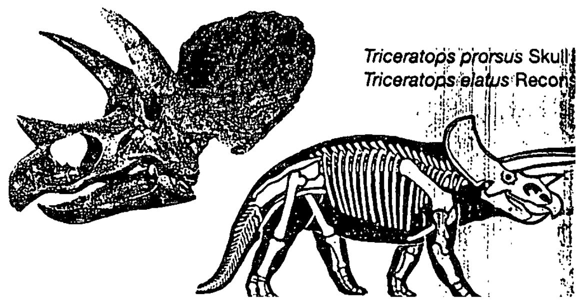
Dinosaurs in the central hall Room 5

The central hall shows skulls and skeletons of different dinosaur species, including *Tyrannosaurus rex*. Detailed illustrated displays show body forms, life habits and sites where the dinosaurs have been found. A rare original skeleton of *Diplodocus*, a present to the Senckenberg when it opened in 1907, is the focal point of the central hall.



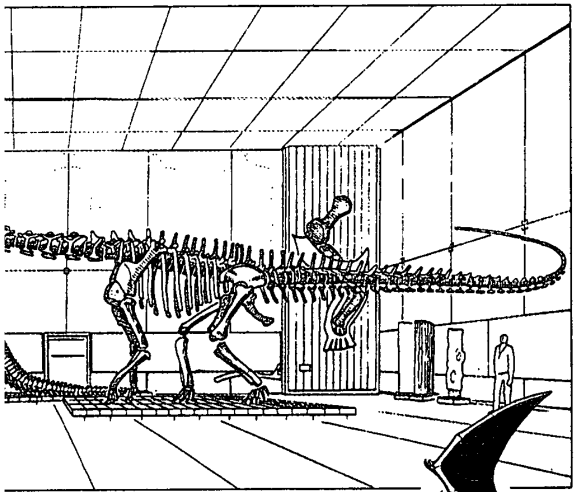
Central hall

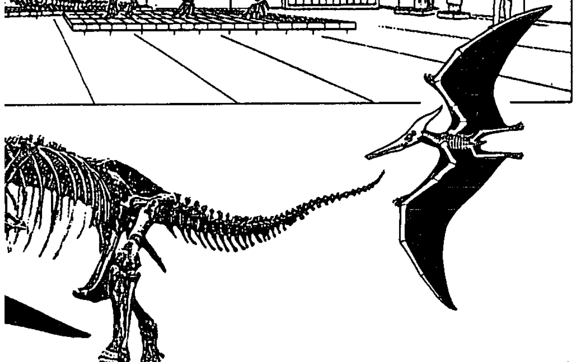




Triceratops prorsus Skull
Triceratops elatus Recon

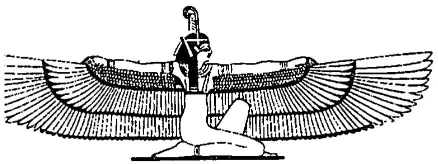
Mummies and mummification in ancient Egypt
Room 4





Prehistoric flying lizard

Tyrannosaurus rex
Skeleton and reconstruction



Egypt exhibition with mummies and artwork relating to Egyptian religion and culture.

Marine saurians, fossil fishes
Room 6

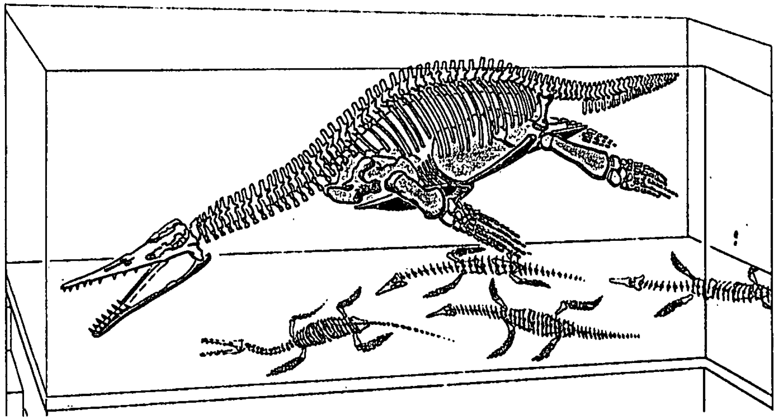
Marine vertebrates of the Mesozoic era

Ostracoderm

Rocks and minerals
Room 7

Minerals with shining colors and diverse crystal structures are the basic elements that make up rocks.

Banded agate



The extremities of the plesiosaurs evolved into long paddle-like organs enabling them to hunt very efficiently.

Edmontosaurus
Room 9

The duckbilled dinosaur is one of the greatest treasures of the museum. Natural mummification makes this specimen unique. You can even see impressions of

Invertebrate animals
Room 7

From the smallest marine snail to the largest living mussel

Origin of m
Room 12-1

The origin, as well as the phylogenetic, individual and cultural development of ma from *Australopithecus* to modern *Homo sapiens*: Detailed, illustrated display accompany the visitor on h trip through the evolution o his own history.

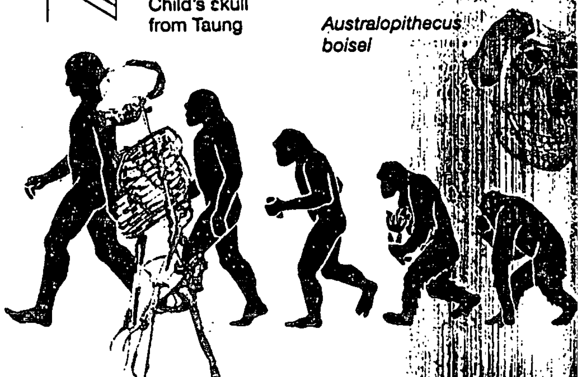
Homo erect

Australopithecus africanus
Child's skull from Taung

Australopithecus africanus

Chimpanz

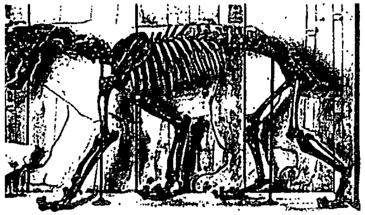
Australopithecus boisei



"Lucy" – Ape or man?
Thus far, *Australopithecus afarensis* is the oldest and most complete skeleton of primeval man with the abili

Fossil mammals and large reptiles Room 8

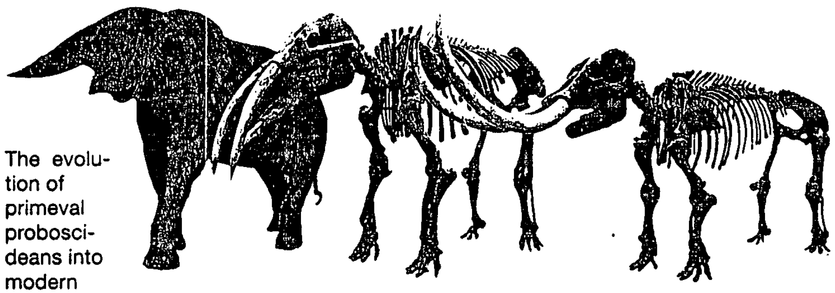
ıg the Ice Age 500000 ; ago elephants, rhino- ɜes, hippopotami, and ɘ-tooth cats roamed lhein-Main area.



ɪabre-tooth ı predator long blade- ːanine teeth

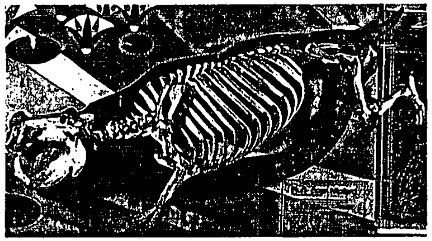
ɪnaconda is to swallow a ɘ capybara.

Whales and elephants in the second hall Room 10



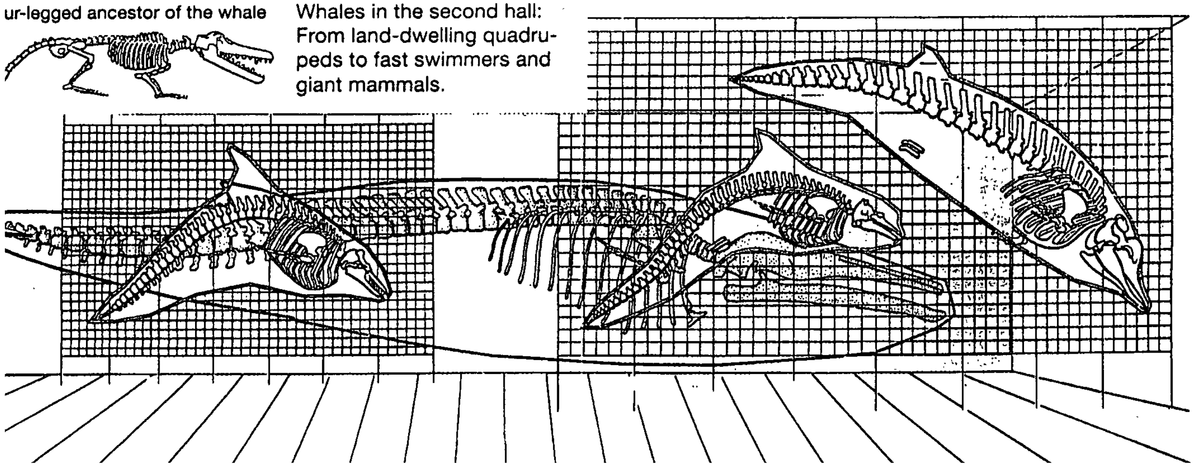
The evolution of primeval proboscideans into modern elephants

The skeleton of a hippopotamus shows the body structure of a familiar zoo inhabitant.



ur-legged ancestor of the whale

Whales in the second hall: From land-dwelling quadrupeds to fast swimmers and giant mammals.



Department of Education

(1996) 1(4)a 4 ... Natur... 126(5)

Guided tours for private groups, school classes, and birthday programs for children:

The Senckenberg Natural History Museum offers a variety of educational activities for adults and children.

To receive information about guided tours, lectures, trips, and holiday programs call (Tel.: 069/7542-357) or visit our updated internet homepage: http://www.senckenberg.uni-frankfurt.de

Opening hours

Everyday: 9 a.m. to 5 p.m.
Wednesday: 9 a.m. to 8 p.m.
Saturday, Sunday: 9 a.m. to 6 p.m.

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