The New Encyclopædia Britannica

in 30 Volumes

MACROPÆDIA
Volume 7

Knowledge in Depth

FOUNDED 1768
15 TH EDITION

Encyclopædia Britannica, Inc.
William Benton, Publisher, 1943–1973
Helen Hemingway Benton, Publisher, 1973–1974

Chicago
Auckland/Geneva/London/Manila/Paris/Rome
Seoul/Sydney/Tokyo/Toronto

First Edition 1768-1771
Second Edition 1777-1784
Third Edition 1788-1797
Supplement 1801
Fourth Edition 1801-1809
Fifth Edition 1815
Sixth Edition 1820-1823
Supplement 1815-1824
Seventh Edition 1830-1842
Eighth Edition 1852-1860
Ninth Edition 1875-1889
Tenth Edition 1902-1903

Eleventh Edition

Twelfth Edition

Thirteenth Edition

Fourteenth Edition

Fifteenth Edition

Printed in U.S.A.

Library of Congress Catalog Card Number: 82-84048
International Standard Book Number: 0-85229-413-1

ENCYCLOPÆDIA
BRITANNICA

MACROPÆDIA

The Encyclopædia Britannica
is published with the editorial advice
of the faculties of the University of Chicago;
a committee of persons holding
academic appointments at the universities
of Oxford, Cambridge, London, and Edinburgh;
a committee at the University of Toronto;
and committees drawn from members of the faculties
of the University of Tokyo
and the Australian National University.

THE UNIVERSITY OF CHICAGO

"Let knowledge grow from more to more
and thus be human life enriched."

Evidence, Law of

To the end that court decisions are to be based on truth founded on evidence, a primary duty of courts is to conduct proper proceedings so as to hear and consider evidence. The so-called law of evidence is made up largely of procedural regulations concerning the proof and presentation of facts, whether involving the testimony of witnesses, the presentation of documents or physical objects, or the assertion of a foreign law. The many rules of evidence that have evolved under different legal systems have, in the main, been founded on experience and shaped by varying legal requirements of what constitutes admissible and sufficient proof. Although evidence, in this sense, has both legal and technical characteristics, judicial evidence has always been a human rather than a technical problem. During different periods and at different cultural stages, problems concerning evidence have been resolved by widely different methods. Since the means of acquiring evidence are clearly variable and delimited, they can result only in a degree of probability and not in an absolute truth in the philosophic sense. Only Soviet doctrine, under the influence of philosophical materialism, expresses a belief that absolute, objective truth can be attained through evidence. In common-law countries, civil cases require only preponderant probability and criminal cases, probability beyond reasonable doubt. In civil-law countries so much probability is required that reasonable doubts are excluded.

THE EARLY LAW OF EVIDENCE

Characteristic features of the law of evidence in earlier cultures were that no distinction was made between civil and criminal matters or between fact and law and that rational means of evidence were either unknown or little used. In general, the accused had to prove his innocence.

Nonrational sources of evidence. The appeal to supernatural powers was, of course, not evidence in the modern sense but an ordeal in which God was appealed to as the highest judge.

Trial by ordeal and battle

The judges of the community determined what different kinds of ordeals were to be suffered, and frequently the ordeals involved threatening the accused with fire, a hot iron, or drowning. It may be that a certain awe associated with the two great elements of fire and water made them appear pre-eminently suitable for dangerous tests by which God himself was to pass on guilt or innocence. Trial by battle had much the same origin. To be sure, the powerful man relied on his strength, but it was also assumed that God would be on the side of right.

Semirational sources of evidence. The accused free person could offer to exonerate himself by oath. Under these circumstances, in contrast to the ordeals, it was not expected that God would rule immediately but rather that he would punish the perjurer at a later time. Nevertheless, there was ordinarily enough realism so that the mere oath of the accused person alone was not allowed. Rather, he was ordered to swear with a number of compurgators, or witnesses, who confirmed, so to speak, the oath of the person swearing. They stood as guarantees for his oath but never gave any testimony about the facts.

The significance of these first witnesses is seen in the use of the German word *Zeuge*, which now means "witness" but originally meant "drawn in." The witnesses were, in fact, "drawn in" to perform a legal act as instrumental witnesses. But they gave only their opinions and consequently did not testify about facts with which they were acquainted. Nevertheless, together with community witnesses, they paved the way for the more rational use of evidence.

The influence of Roman-canonical law. By the 13th century, ordeals were no longer used, though the custom of trial by battle lasted until the 14th and 15th centuries. The judicial machinery destroyed by dropping these sources of evidence could not be replaced by the oath of purgation alone. With the decline of chivalry, the flourishing of the towns, the further development of Christian theology, and the formation of states, both social and cultural conditions had changed. The law of evidence, along with much of the rest of the law of Europe, was influenced strongly by Roman-canonical law elaborated by jurists in northern Italian universities. Roman law introduced elements of common procedure that became known throughout the continental European countries and became something of a uniting bond between them.

Under the new influence, evidence was, first of all, evaluated on a hierarchical basis. This accorded well with the assumption of scholastic philosophy that all the possibilities of life could be formally ordered through a system of a priori, abstract regulations. Since the law was based on the concept of the inequality of persons, not all persons were suitable as witnesses, and only the testimony of two or more suitable witnesses could supply proof.

The formal theory of evidence that grew out of this hierarchical evaluation left no option for the judge: in effect, he was required to be convinced after the designated number of witnesses had testified concordantly. A distinction was made between complete, half, and lesser portions of evidence, evading the problem posed by such a rigid system of evaluation. Since interrogation of witnesses was secret, abuses occurred on another level. These abuses were nourished by the notion that the confession was the best kind of evidence and that reliable confessions could be obtained by means of torture.

Despite these obvious drawbacks and limitations, through the ecclesiastical courts, Roman-canonical law gained influence. It contributed much to the elimination of nonrational evidence from the courts, even though, given the formality of its application, it could result only in formal truths often not corresponding to reality.

A COMPARATIVE SURVEY OF THE PRINCIPLES OF LEGAL EVIDENCE

A comparison of the principles of evidence under different legal traditions can best be made by examining the rights and obligations of the plaintiff and the defendant in civil proceedings and of the prosecutor and the accused in criminal proceedings. The position of the judge is also crucial. Historically, two systems developed.

The inquisitorial system. The first, which may be called the inquisitorial system, had its origins in medieval Roman-canonical proceedings. It is distinguished by the active part played by the judge, who by virtue of his office, himself searches for the facts, listens to witnesses and experts, examines documents and orders the taking of evidence. In continental European countries, and those other countries that derive their law from them, this system has generally been retained for criminal proceedings. The prosecutor and the accused, of course, give their recital of the facts and indicate their evidence for specific assertions. But by virtue of his role in the case, the judge must make further investigations if he deems them necessary to obtain the truth. Under the Soviet code of civil procedure of 1964, this system is also applied to civil pro-

The judge's role in continental Europe

ceedings. Other Socialist countries have followed this example. In some western European countries, there is a definite inclination toward employing this inquisitional system in all legal proceedings that have, or could have, a substantial public legal impact; *e.g.*, matrimonial, status, administrative, social, labour, and financial matters.

The accusatorial (adversary) system. The second system, which employs what are usually called accusatorial or adversary principles, is used in the common-law countries for all civil and criminal cases. In this system, the parties and their attorneys are primarily responsible for finding and presenting evidence. The judge does not himself investigate the facts. Only if the efforts of the parties are incomplete must the judge make inquiries with regard to questions that have remained unanswered.

In civil matters, most continental European countries follow a mixed system of both principles. In some of these countries, the judge can, for example, hear witnesses who have not been designated by the parties, and in all countries he can, by virtue of his office, hear the parties and experts and order documentary evidence or the actual inspection of evidence. In contrast to criminal cases, the continental European judge is always bound by the motions and assertions of the parties—a situation that does not, however, obtain under Soviet law.

Oral proceedings. Under both systems of presenting and obtaining evidence, oral proceedings are generally accepted. The written proceedings favoured during the Middle Ages have been abolished, although the parties prepare their lawsuits through briefs, and parts of the preliminary proceedings can be handled in writing. The interrogation of witnesses, however, is oral. The Roman-based countries and Sweden, Austria, and the Soviet Union do not permit any exceptions, while other countries, such as Germany, permit written statements by witnesses in special cases and with the consent of the parties. In the common-law countries, an exception is made to the principle of oral proceedings for certain types of affidavits, and, particularly in civil cases, the practice has steadily gained in importance.

Direct interrogation of witnesses by the deciding court is an aspect of the law of evidence closely connected with oral proceedings. Generally, in continental European countries, witnesses are interrogated by the judges who decide the verdict, but a number of countries have an investigation procedure according to which another judge, or only one member of the judging body, interrogates the witnesses. Under both the inquisitorial and the accusatorial systems, the principle of direct interrogation is of special importance in the free consideration of evidence. In the common-law countries, the function performed by the judge in this regard is handled by attorneys for the prosecution or defense, with the judge's role restricted almost entirely to overseeing the questioning.

Another principle of substantial importance is the public trial, which was one of the aims of the French Revolution. The right to a public trial, long established under the common law, is now accepted by all continental European countries. There may be exceptions, however, if questions of morals or public order are involved, and public trials in the full sense need not be provided in circumstances in which the evidence, rather than being taken in open court, is heard before a *juge d'instruction* or examining magistrate.

Influence of the jury

One major influence that has shaped the law of evidence has been the jury system. At least one writer has said that law of evidence is the child of the jury. Oral proceedings, direct interrogation and the public trial are much less problematic under the Anglo-American system than under the civil-law system to the extent that evidence is heard before the jury. But this system has spawned a large number of regulations for the admissibility of evidence in order to guarantee due process and fair procedure and to protect the jury from being misled. The initiative of the parties determines the handling of these regulations, for they must raise objections if, in their opinion, any of the numerous exclusionary rules is being violated. The judge then rules on the objection. By the complex working of this arrangement, the Anglo-American system has become more formalistic in many respects than the continental European system.

The burden of proof. The burden of proof is a manifold and somewhat ambiguous concept in the law of evidence.

The burden of producing evidence means that in general the party that cites specific facts for the substantiation of its claim also has the burden of producing the evidence to prove these facts. This burden depends on the substantive law governing the claim. Permissible presumptions and legal rules can shift the burden in various situations.

The burden of conviction, on the other hand, comes into play at the end of the hearing of evidence, if doubts remain. This is simply to recognize that the evidence is not sufficient to convince the jury or the judge and that, in general, the party having the burden of pleading and producing facts favourable to itself and of giving evidence also carries the so-called burden of conviction.

Difference between the burden of proof in civil and criminal proceedings

Whereas, in civil proceedings, it is generally the plaintiff who has the burden of proof for facts supporting a claim, unless this burden has been shifted to the defendant through rules or presumptions, in criminal proceedings it is the prosecution that bears the burden of proof for all relevant facts. What this means is that the defendant cannot be found guilty as long as proof has not been supplied or as long as doubts still remain. In continental European law, no distinction is made between civil and criminal cases with regard to the standard of proof. In both, such a high degree of probability is required that, to the degree that this is possible in the ordinary experience of life itself, doubts are excluded and probability approaches certitude. In the common-law countries, the degree of probability required in civil cases is lower than that called for in criminal matters. Since, according to socialist rules of civil procedure, the judges themselves must search for the facts, it is dubious whether one can speak at all of a burden of proof under socialist law.

Relevance and admissibility. In civil proceedings that are determined by the adversary principle, evidence is both ascertained and simultaneously restricted by the assertions of the parties. If the allegations of one party are not disputed or contested by the other, or if the allegations are even admitted, then no proof is required. Proof would, in fact, be irrelevant. Evidence offered to prove assertions that are not in issue nor probative of the matter in issue would also be irrelevant. The only evidence that is, therefore, relevant, is evidence that to some degree advances the inquiry and has a probative value for the decision. While continental European judges, in ordering the hearing of evidence or in deciding on evidence, indicate the facts to be proved and thereby strictly eliminate irrelevant facts, Anglo-American judges first give the parties an opportunity to furnish any evidence that they deem suitable. If, during the hearing of witnesses, irrelevant questions are put, they are rejected after the adversary has objected to them.

It has been said that relevance depends on logical considerations and that admissibility depends on the law. In contrast to continental European law, the common law has developed a large number of rules governing the admissibility of evidence. Relevant evidence is not admissible, for example, if the witnesses are excluded from testifying because of incompetency, or if they are protected by privileges against self-incrimination, or in instances in which they would have to divulge confidential or professional communications that have a privileged status or government secrets, or, again, when the evidence is excluded by the rules against hearsay.

In criminal cases in which the adversary principle does not govern, relevance relates to such questions that are so far removed from the case that they have no evidence value at all. Admissions and confessions do not exclude further evidence. According to Anglo-American law, the accused may be a competent witness under the admissibility rules, but, in contrast to an ordinary witness, he has the privilege of not taking the witness stand. According to continental European law, the accused is neither a party nor a witness. He can be heard, but he cannot be forced to answer questions of fact. In general, Anglo-

American rules of admissibility apply to criminal proceedings much as they apply to civil cases.

The free evaluation of evidence. Freedom to evaluate all the evidence produced was established in Roman law but fell into disuse as a principle during the time of the formalistic Roman-canonical law of evidence that characterized the Middle Ages. Remnants of the medieval formal theory of evidence survive in various countries.

Conviction intime: the judge's opinion

In countries where remnants of the medieval formal theory of evidence are still preserved, the principle of free evaluation of the evidence by the judge generally dates from the French Revolution. The French introduced the concept of the judge's *conviction intime* (inner, deep-seated conviction) in contrast to rules of formal evidence that prescribed exactly when the evidence amounted to proof. The primacy this gave to the personal conviction of the judge meant that it was not even necessary to state the reasons for the inner conviction. This total dependence on the judge's discretion aroused a great deal of criticism, and, as a result, various judicial codes prescribed that in giving the grounds on which judgment was based, the judge had to specify in writing why he was convinced in each case. *Conviction intime* in its original sense is limited to the testimony of witnesses and experts and to the explanations of the parties. Both kinds of formal oaths made by parties to a case, the supplementary oath and the tendered oath, are still valid in Roman-law based countries, and both may lead to formal solutions, since the judge must follow the legal consequences of the oath. But these survivals of medieval formal evidence theory have been weakened. In France, for example, the judge's latitude under the principle of *conviction intime* has been extended to allow him to pass on the affirmation oath of the party, which formerly had to be given a certain value, regardless of his opinion of its worth. In other states, such as Austria, Germany, and the Scandinavian countries, the formal oath of the parties was abolished and replaced by the free depositions of the parties. Even if the parties take an oath on their testimonies during this process, the judge is not bound by it but may still make his own evaluation of the evidence. In addition, some remnants of the formal evidence theory have been preserved with regard to documentary proof where rules of procedure contain presumptions as to the conclusiveness of certain documents. Since reliance on documentary evidence prevails in some countries, these formal evidence rules are still of special importance.

In Anglo-American law the problem of free evaluation of evidence can be understood through the institution of the jury. Obviously, the evidence must be convincing to the common sense of the jury members, who form their judgment on the basis of free conviction. The function of the jury, however, is to decide questions of fact, rather than questions of law, which are left to the judge. The jury's verdict can be overturned by the judge if it is inconsistent with the evidence, or with his instructions as to the law governing the case. The judge's relationship to the jury therefore plays a role in the decisions, and there are difficult questions in which it is unclear whether the jury or the judge should consider the evidence. Some formal rules of evidence survive in Anglo-American law. In some cases evidence must be corroborated before it can constitute proof. In homicide cases, for example, a confession must be supported by additional evidence. In addition, evidence by witnesses is sometimes excluded by rules of admissibility.

Soviet and Swedish innovations

In recent years, some new principles for the evaluation of evidence have become evident in the law of Sweden and the U.S.S.R. Both countries have rejected all remnants of the formal theory of evidence, and both have tried to render the judges' conviction objective. Sweden demands that its judges undertake a discursive analysis of all the evidence. The Soviet procedure calls for judges to form their conviction on the strength of the evidence and according to their "socialist legal conscience."

THE CLASSIC MEANS OF PROOF

According to Anglo-American law, the classic means of proof are witnesses, documents, and real evidence (derived from the actual inspection of objects). As a result of historical development, the status of witness was accorded to experts and to the parties in a civil lawsuit, and even to the accused in criminal proceedings. The development of continental European law has taken a different course. Parties cannot be witnesses, and evidence by experts is subject to special procedural rules. Consequently, there are essentially five separate sources of evidence: witnesses, parties, experts, documents, and real evidence.

Oral testimony. The oral testimony of witnesses competes in a sense with documentary evidence to the extent that one may exclude or supplement the other.

The importance of documentary evidence in some continental European countries goes back to the year 1566 and the French Ordinance of Moulins, which stated that contracts above a certain value could only be concluded in writing with the aid of a notary. This preference for documentary proof has persisted in articles of the French code of civil procedure and in other civil codes. According to the French practice, evidence by witnesses is excluded in the case of contracts above a certain value. But this strict regulation has been made more flexible by the growth of doctrine permitting evidence by witnesses once the origin of written proof is furnished and is not sufficient, or if the contracts in question are commercial in nature, or if it is impossible for one party to prove its claim through documents. Facts extrinsic to the document cannot be proved through witnesses. Even Soviet law prescribes that in special cases proof can be furnished only through documents.

Eligible witness. Under Anglo-American law, almost anyone can be a witness, including the parties and experts; even insane persons, children, and convicted felons may testify. Grounds once used for excluding such persons as witnesses are now used only to impeach their credibility. Continental European countries, as has been said, do not treat either the parties or experts as competent witnesses, and they are still suspicious of interested witnesses. Some of them, influenced by the Roman-based school, deny, on the whole, the capacity of those persons having a certain degree of relationship to the parties. Some consider insane persons incompetent to testify, others grant them the competency but exclude their testimony on the grounds of credibility. The capacity to be a witness does not depend on whether or not the person can testify about questions relevant to the specific case. In general, the tendency has been to utilize all persons who can testify about facts that will help to establish the truth. Competency as a witness has therefore been extended to as many persons as possible. On the other hand, many persons are protected by law from being forced to testify. This type of protection derives either from privilege, or from the right to refuse to give evidence, either case distinguishable from incapacity to testify. Whereas privilege or the right to refuse to give evidence may be either requested or waived, incapacity to testify takes effect automatically; *i.e.*, it must always be officially considered by the court.

Refusal to testify

Privileges. Privileges under Anglo-American law must be distinguished from the right to refuse to give evidence under particular circumstances as it exists in continental European practice. The latter is granted to witnesses for either personal or objective reasons. The personal reasons are the same as those that result in incapacity to testify under Roman-based law; *i.e.* relationship, affinity, and marriage. The objective reasons concern persons who, as a result of their profession (for example, clergymen, physicians, attorneys, journalists, etc.), have been put in possession of confidential facts. Such confidants have a limited right to refuse to give evidence so long as the person protected does not give his consent (the German solution). In some cases they are not admitted as witnesses without the consent of the protected person (the Swedish solution). Thus the Swedish judge officially decides whether the protected person has given his consent, whereas the German judge leaves the decision whether to testify up to the confidant. In addition, witnesses may refuse to testify if their testimony would cause direct financial damage to themselves or to their

families, or if it would publicly disgrace them or expose them to criminal prosecution. All persons may make their own decision as to whether or not they wish to testify, but judges are obliged to inform them about their specific rights in the matter. These procedural regulations have developed in order to avoid the situation in which the person protected becomes caught in a conflict between the truth and his personal interests. The interests of the protected person—perhaps partly out of realism—are thus given a higher value than the search for the facts. In this regard, Soviet law has adopted a different attitude, which places a higher value on objective truth than on the personal rights of third persons who, though not parties to a suit, may become involved as witnesses.

The Anglo-American privileges differ from the continental European right to refuse to testify insofar as privileged persons cannot decide whether or not they wish to testify. They may only cite their privileges, and the judge decides if they must testify. Under a system that stresses the free evaluation of evidence, the obligation to testify is subject to only a very few exceptions.

Self-incrimination. The privilege against self-incrimination has a twofold nature in Anglo-American law because, in civil proceedings, parties may appear as witnesses and, in criminal proceedings, the accused may appear as a witness. The privilege of an ordinary witness is considerably limited. He must submit to being designated and sworn in as a witness in all instances and must answer all questions except those which are self-incriminating. Consequently, either he or his attorney must sift out the incriminating questions that will evoke the privilege. This is not always easy, particularly since it is only the witness, and not the party or the party's attorney, who may cite the protecting privilege. Critics have called this privilege a sentimental institution, but it is worth noting, in this regard, that the privilege against self-incrimination was included in the U.S. Bill of Rights.

Personal and professional privilege. Privileges deriving from personal and professional relationships are generally not granted on principle, though historically a privilege for the protection of marital communications has developed. In England, an 1853 law decreed that a husband could not be forced to testify concerning information that his wife may have given him during the course of the marriage. This, naturally, also applies to the wife. In the United States, the courts contended that laws concerning testimony on matrimonial communications contained only a statement of the common law. Only the beneficiary of the privilege may cite it, and it is not applicable where criminal offenses by one spouse against the other or against the children are concerned, or in the case of a divorce proceeding.

Attorneys are considered to be under an obligation to refuse to testify about confidential communications with their clients. The privilege, however, protects the client, not the attorney, and, therefore, the client may waive it. This privilege is only properly explained in terms of the adversary system, which, so to speak, makes the attorney his client's champion.

Clergymen are likewise under obligation to refuse to answer questions concerning information given them in the secrecy of the confessional by believers. Again, the privilege protects the believer. This custom has been sanctioned by legislation in many U.S. states. In England, however, there is no common-law rule for this privilege.

Physicians, as a rule, must answer all questions since there is no common-law privilege regarding confidential information furnished by the patient. In some states an appropriate privilege has been created by legislation. In these states, it is again the patient who is protected and only he may waive the privilege.

The journalist and his source

Journalists, like physicians, occupy a position that is not entirely clear. In some jurisdictions they may refuse to testify about their sources of information, and in a number of U.S. states such a privilege has been specifically created by statute. In other U.S. states and in England the question does not yet seem to have been settled.

Privilege in civil and criminal cases. Differences between civil and criminal proceedings regarding the availability of privilege grow out of the protection from self-incrimination. It has already been pointed out that the accused no longer lacks competence as a witness but may exercise the privilege of refusing to be called or sworn as a witness. Unlike ordinary witnesses, the defendant may invoke this privilege with considerable latitude. But, if he does decide to step into the witness box, he renounces his privilege and may be interrogated as if he were an ordinary witness. The question arises, however, whether the waiving of the privilege against self-incrimination is limited to testimony concerning crimes of which he presently stands accused, or whether he must answer all questions regarding criminal acts. It appears to have become fairly well established that the prosecutor can, in fact, interrogate the defendant about previous criminal offenses. In civil cases, the parties have the same privilege for protection from self-incrimination as other witnesses; *i.e.*, they need not answer incriminating questions.

Methods of establishing the credibility of witnesses. Means for establishing the credibility of witnesses assumed a great deal of importance at the point when medieval formal evidence theory was replaced by the free judicial consideration of evidence.

The swearing of witnesses

The oath, perhaps the oldest means for encouraging truthful testimony, antedates this point, of course. The oath, in some sense, forms a link between court proceedings and religious belief since, in its usual form, witnesses swear by Almighty God that they are speaking the truth. Though the effectiveness of such an act has certainly diminished in secular societies, this appeal to God has for centuries been considered the surest means of obtaining truth. There are two kinds of oaths, the preliminary and the subsequent. In Anglo-American practice, the witness is sworn in before testimony. Under the German and other continental procedures, the swearing-in may occur after testimony as well. The latter method allows the judge to use his own discretion in individual cases as to whether or not the witness should be ordered to swear. In current German practice, very few witnesses are sworn in for testimony in civil proceedings, whereas in criminal proceedings all witnesses have to swear. Some continental European countries allow witnesses who object to oaths to substitute a solemn affirmation, and Denmark has abolished all oaths in legal procedures. Only Soviet law, intent on breaking with tradition, forbids any oath or solemn affirmation. The oath of a witness does not have the formal effect of binding the judge or the jury. They must evaluate it and testimony freely.

The cross-examination. Common-law judges and attorneys regard the opportunity to cross-examine as a guarantee of the reliability and completeness of testimony by a witness. Under the perfect operation of the adversary system it is not the judge but rather the parties or their attorneys who interrogate the witnesses. The plaintiff's attorney begins the "examination in chief," which is subject to a number of restrictions. Leading, misleading, and argumentative questions, for example, are not permitted. After the plaintiff's attorney concludes his interrogation, the defendant's attorney may cross-examine the same witness. This cross-examination generally consists of leading questions posed with the intent of weakening or invalidating the impression created by the direct testimony of the witness. The cross-examination must ordinarily be limited to subjects covered during direct interrogation. There is a recognizable tendency, however, for cross-examination to become as open-ended as possible. The plaintiff's attorney has the option, finally, to re-establish the credibility of his witness by re-examination. These interrogations are formally regulated and require a great deal of skill and experience on the part of the attorneys. Such formal questioning of the witness is unknown to the continental European rules of procedure, even though cross-examination is common. Continental rules of procedure require the judge to interrogate the witness first. Frequently, the witness begins with a free narration. Then, after the judge has finished his interrogation, the attorneys of both parties may question the witness. All this is done in an informal manner, and almost any question is permitted. In Roman-law countries

the interrogation of witnesses is, however, rather formalistic because it is generally limited to questions concerning allegations specified in the evidence judgment. But here too, there is a tendency for the court to allow questions at its discretion.

The witness as "real evidence." Scientific examinations of witnesses are especially common in paternity and status proceedings with regard to blood-typing. These methods have now been so much improved that the suspicion of paternity may be definitely dismissed in many cases. In Germany and elsewhere, opinions based on biological and hereditary evidence are used for these same purposes. The use of fingerprint and ballistics evidence, among other types, has become quite customary in criminal cases. In the United States, there are varying opinions about the admissibility of lie-detector tests as evidence. The results of such tests are not yet admissible in the continental European countries.

The hearsay rule. The hearsay rule is perhaps the most characteristic feature of the Anglo-American law of evidence. It has also been said that, next to trial by jury, the hearsay rule constitutes the most important and original contribution of this system's practice.

Despite the obvious dangers involved in its use, free evaluation of the evidence furnished by hearsay testimony continues to be characteristic of continental European law. This somewhat surprising fact may be explained by reference to the historical development already traced here. Until the 19th century, the medieval formal evidence theory strictly prescribed when the judge had to be convinced by the testimony of a witness. Moreover, there was no jury in the continental countries to be protected by rules of evidence and therefore no need to introduce rules of hearsay. When the formal evidence theory was replaced by the requirement that the judge freely consider the evidence, his discretion naturally extended to hearsay testimony.

The creation of a body of rules for the exclusion of hearsay evidence was motivated by the arguments that such testimony could tend to mislead the jury, that the hearsay observer, unlike the legal witness, was not under solemn oath and was inaccessible to cross-examination, that such testimony furnished third-hand evidence, and that it violated the best evidence rule.

The exceptions to the rule against hearsay

Over the years, exceptions to the prohibition of hearsay testimony had to be permitted, however, and these have become so numerous that the opinion has sometimes been expressed that no exhaustive list of such exceptions could even be compiled. The judge must decide in each case whether testimony based upon hearsay is admissible under an exception to the rule—a further indication that regulations governing the admissibility of evidence are far more important in Anglo-American law than in continental law. The most commonly cited exceptions to the rule of hearsay relate to statements made by dead or absent persons, statements in public documents, and to confessions and admissions by parties.

Confessions. Confessions, as a source of evidence, are distinguished from admissions. Whereas a confession is a complete acknowledgment of guilt in criminal proceedings, an admission is a statement of fact in either a civil or a criminal case. In former times, the confession was considered the ultimate form of evidence. As soon as the accused confessed—often under duress—no further proof was required. In time, involuntary confession came to be rejected as evidence under English law, and the burden of proving that a confession was voluntary lay with the prosecutor. In the United States, the federal rule that confessions are inadmissible if obtained while the defendant was unlawfully detained has not gone quite so far, though the law is still in a state of considerable flux. Involuntary confessions, however, are not admissible for any purpose under Anglo-American law. In continental European law, on the other hand, confessions of the accused are always freely considered by the judge.

Differences between criminal and civil proceedings regarding admissions result mainly from the adversary principle governing civil proceedings. In Anglo-American procedure, if one party in a civil suit admits facts contrary to his interest, such an admission is conclusive and obviates the need for further evidence on the point. The same result follows in German or Swedish courts. Under the Roman-based laws of such countries as France, Italy, and Spain, an admission made before the court is a form of evidence that leads to conclusive proof binding upon the court. But admissions made out of court are subject to free evaluation by the judge and do not exclude further evidence. Only Soviet law gives no binding effect to admissions.

Party testimony in the continental European countries. Oral testimony by the parties in civil proceedings was introduced in Austria in 1895. Norway followed suit in 1915, Denmark in 1919, Germany in 1933, and Sweden in 1948. Party testimony is generally heard in the same way as the evidence of other witnesses, but there are some essential differences. For one thing, the interrogation of parties is a subsidiary source of evidence to be used only when all other means have been exhausted, but it may be also used together with other means of proof. In some countries, both parties must be heard; in others, only one party may be heard upon motion of the opponent. In most cases, the parties do not have to confirm their testimony by oath, but the court may decree that one of the parties must swear. In Swedish law, for example, the parties must solemnly declare that they have told the truth. In Soviet law, however, the interrogation of parties is completely informal.

In criminal proceedings under continental European law, the defendant may be heard, but his formal position is that of neither a witness nor a party. His depositions, nevertheless, do have value as evidence.

Expert evidence. Expert witnesses must have specialized knowledge, skill, or experience in the area of their testimony. For the most part, they do not testify concerning facts but draw inferences from them. With a few exceptions, they are treated in Anglo-American law as ordinary witnesses and are brought before the court by the parties in the same manner as other witnesses. Although ordinary witnesses are generally allowed to testify only concerning facts and not to express opinions, an exception to this rule is made for the expert, who must, of course, be allowed to give his opinion.

Qualifications of an expert witness

Generally speaking, anyone with special knowledge may be an expert in his respective field. In Anglo-American law, the expert is designated by the party, while in continental European law the court decides who may be an expert, generally selecting from a list on file in the court so as to guarantee that the experts designated are impartial. Experts may not, therefore, be cited by the parties.

The oral interrogation of experts is customary in Anglo-American law, and proceeds, with a few exceptions, under the same rules for the interrogation of ordinary witnesses.

Under continental rules of procedure, on the other hand, expert opinions are generally given in written form. Experts are allowed a rather wide scope of discretion, especially when the opinion involves scientific findings that often cannot be checked by the judge. But under some continental European rules, the parties or their attorneys may request that the experts testify before the court to defend their written opinion and tell how they arrived at it.

Documentary evidence. Documentary evidence is in many respects considered better than the evidence furnished by witnesses, about which there has always been a certain amount of suspicion. Documentary evidence differs considerably from the evidence of witnesses and is dealt with under special rules.

Criteria for establishing the authenticity of documents are only important if authenticity is contested. This is often impossible, however, if a presumption favouring the authenticity of a public document exists—which it frequently does under continental European law. Under Anglo-American law, a party may serve the adversary with a written request to corroborate the authenticity of any relevant document. Direct evidence of authenticity may be gotten through the testimony of persons who

signed the original documents. This is often impossible, however, and in this case circumstantial evidence is permitted. Under Roman-based law, documents are proved genuine by special proceedings. In other continental European countries, a document may be proved genuine by any type of evidence.

The obligation to present documents in the Anglo-American system derives from what is known as the best evidence rule. If the original document is in the hands of a third person or the opponent, the party that must supply proof can ask the court for a writ of *sub poena duces tecum* compelling the third party to produce the document in court. If the original is not produced after this, second-hand evidence of its existence is then permitted. In continental law, there is no similar obligation to produce documents. The adversary or third persons can only be ordered to do so if there is a positive obligation under the substantive law. Among European countries, only Sweden has developed any extensive obligation for the parties to produce documents. Soviet law has gone farthest in this regard, extending the rule to all kinds of documents regardless of the interests of third parties.

Proof of documentary evidence

Extrinsic proof of the contents of documents in Anglo-American law is admitted only in special cases, since oral evidence is inadmissable to vary, contradict, or add to the terms of a written agreement—a rule that makes many documents conclusive as evidence. The method of Anglo-American law in this particular area is consequently negative, since evidence outside the content of the document is on principle not admissible. Continental law follows the medieval method, by attributing a certain value as evidence to particular documents, which is binding on the judge.

The consideration of documentary evidence by the judge therefore tends to be restricted, since the document itself furnishes conclusive proof if evidence by reference to facts outside the document is inadmissible. In most continental laws, judges are bound by presumptions in this respect, and only in Swedish and Socialist law are there no provisions restricting free judicial consideration of documentary evidence.

Real evidence. The remaining form of evidence that needs brief mention in this survey is so-called real evidence, also known as demonstrative or objective evidence. This is naturally the most direct evidence, since the objects in question are inspected by the judge or jury themselves. Problems arise in this area over who is obliged to present objects for inspection or to actually undergo inspection. The use of the jury system in Anglo-American law has made it necessary that any real evidence be shown to be both logically relevant and completely genuine before it may be admitted as proof. The exhibit of real evidence may sometimes be directly connected with the case (for example, when a weapon is shown to the court), or it may involve something used to illustrate testimony, as, for example, a model or skeleton to clarify testimony about an injury. In any case, real evidence may not be accepted as legal proof unless it is authenticated by the testimony of witnesses.

ADAPTATIONS OF THE BASIC SYSTEMS

Generally speaking, two different systems of the law of evidence are prevalent all over the world: the Anglo-American and the Continental European systems. The latter can be subdivided into three variants: the Germanic, the French or Roman, and the Socialist patterns. The Germanic variant tries to utilize all means of proof; it follows the principle of formlessness and balances between the accusatorial and the inquisitorial principles. The French or Roman variant favours evidence by documents and is dominated by a very formal procedure of "enquête" or investigation. The Socialist variant makes believe that objective truth might be ascertained by evidence. It therefore favours the inquisitorial principle and does not protect witnesses, parties, and experts by privileges or procedural rights.

Japan provides an interesting example of mixture of the Continental European system (Germanic and Roman variants) with the Anglo-American system with the continental model dominating, however. This can be seen historically. With the Meiji revolution in 1868 Japan began to adopt Western practices, including European law; so that eventually Japanese ideas of the law of evidence were replaced by European ones. The drafters of the first civil code of procedure in 1890 surveyed many legal systems, including the French, taking something from each. Their final product is, however, characterized as following the first draft of the German civil code. In its subsequent development, the Japanese legal system remained true to these sources, even in the development of a new code in 1929.

After the Second World War under American influence this code of civil procedure was changed in many respects; at the same time the Japanese code of penal procedure was changed.

In criminal procedure the Anglo-American influence can be found in several rules. The inquisitorial principle, for instance, lost its dominating place in favour of the accusatorial principle; it is not the judge but the defendant and his counsel who question witnesses. Evidence by hearsay is no longer allowed. Instead of the inquisitorial hearing of the defendant there is the hearing of the defendant as a witness. The fusion of the Continental European with the Anglo-American system of evidence leads to an unique combination of the interests of the defendant with the principle of impartiality of the court.

In Japanese civil procedure, however, the Continental European law of evidence still dominates. The Japanese adhere to the five classical means of proof: witnesses, experts, parties, documents, and real evidence. The hearing of witnesses is done by the parties and their counsels. The party that asked for the hearing of any person will start with the examination; thereafter the other party will cross-examine. But contrary to the Anglo-American law of evidence there are no strong admissibility rules regarding examination, cross-examination, and re-examination. Contrary to criminal procedure, the hearsay rule is allowed in civil cases. When the parties have finished their examinations, the judge can put questions to the witness or experts. As in the Continental European system, persons on the witness stand have no special privileges, though they have the right to refuse to give evidence that might lead to self-incrimination, the incrimination of relatives, or the revelation of state secrets.

There seem to be no current moves to change the law of evidence as it is now in force in Japan, perhaps because it was changed too often during the last hundred years.

BIBLIOGRAPHY

Historic development: T.F.T. PLUCKNETT, *A Concise History of the Common Law*, 5th ed. (1956); A. ENGELMANN, *Der Civilprozess Geschichte und System* (1889; Eng. trans., *A History of Continental Civil Procedure*, 1927); R.C. VAN CAENEGEM, "La Preuve dans le droit du moyen-âge occidental," *Recueil de la Société Jean Bodin*, vol. 17 (1965); H. NOTTARP, *Gottesurteilstudien* (1956), particularly for ordeals.

American law: C.T. MCCORMICK, *Law of Evidence* (1954); J.H. WIGMORE, *The Principles of Judicial Proof*, 2nd ed. (1931).

English law: G.D. NOKES, *An Introduction to Evidence*, 3rd ed. (1962); R. CROSS, *Evidence*, 4th ed. (1967); S.L. PHIPSON, *Manual of the Law on Evidence*, 10th ed. (1963).

German law: A. BLOMEYER, *Zivilprozessrecht* (1963).

Italian law: M. CAPPELLETTI and J.M. PERILLO, *Civil Procedure in Italy* (1965).

French law: *Répertoire de procédure civile et commerciale*, 2 vol., in the "Encyclopédie Juridique Series" (1955–56).

Spanish law: L. PRIETO-CASTRO, *Derecho procesal civil* (1964).

Swedish law: P.O. EKELOF, *Rättegång* (1963–66).

Soviet law: A.J. WYSHINSKII, *Theorie der gerichtlichen Beweise im sowjetischen Recht*, 3rd ed. (1955); H. ROGGEMANN, *Die Zivilprozessordnung der RSFSR* (1964).

For a comparative study of the laws of evidence in Germany, England, France, Italy, Spain, Sweden, and the Soviet Union see H. NAGEL, *Die Grundzüge des Beweisrechts im europäischen Zivilprozess* (1967).

(H.N.)

Evolution

Man's interest in his own origin, that of all living things, and that of the universe must be as old as man himself. It is reflected in literary form (which must itself be based on much older creeds) in legends of creation popular among the peoples of antiquity—Sumerians, Egyptians, Greeks, and Hebrews, whose sacred book, the Old Testament, contains two descriptions of the creation and traces of a third. The omnipotence that primitive peoples ascribed to their deities made it natural for them to believe that whatever is was created. This is the reason that problems surrounding the origins of the earth, heavens, seas, plants and animals, men and women were wrapped in unquestioned and unquestionable dogmas, some of which still hold sway. It is only comparatively recently, in societies and civilizations possessed of scientific knowledge and methods of investigation, that such dogmas have come under question. The Copernican system dethroned the geocentric view of the universe. Evolution, the changes that living beings are now known to have undergone since the origin of life on earth, has led to an even more profound revolution in the history of ideas because it has revealed the affinity of man to all other living beings and has shown that change, not stability, is the rule of life.

Evolution is the kernel of biology. It is significant that, before Charles Darwin established evolution as an inescapable fact and showed how it was brought about, biology was in a state of chaos. Organisms are found only as species, groups of individuals that resemble one another more than they resemble any others and that breed only among themselves, a concept that first became precise in the 17th century, when, however, each species was regarded as a product of the original creation, and no explanation was provided or even sought for the countless puzzles that presented themselves: why species differ from one another, what relation there was between living forms and the fossils found in the crust of the earth, why some organisms are found only in certain regions, why internal parasites such as the tapeworm infest man, and many other questions. Evolution provided the first unifying, general principle applicable to all living beings, which are as they now are because they have become what they are, having undergone modification during descent from other species.

Another aspect of the significance of evolution is that any fact discovered about one species may be applicable to other species, and, as the study of biology progressed and became diversified into many branches—including comparative anatomy, embryology, paleontology, genetics, physiology, etc.—each of these branches may have lessons for the others. The understanding of any biological phenomenon is helped by knowledge of evolutionary principles and mechanisms, and many phenomena are inexplicable without evolution.

Evolution also has practical significance for man. The art and practice of medicine are the outcome and integration of studies in many branches of biology and would make no progress without a realization of, for example, evolutionary changes in bacteria and viruses. Agriculture, including plant cultivation, animal domestication, and selective breeding, depends heavily on the application of evolutionary principles. Ethology, the study of behaviour, has yet to find the evolutionary basis for man's aberrant conduct that allows him to kill members of his own species wholesale, which other species do not do. The social importance of evolution in understanding human conduct in the past and in providing guidelines for the future is enormous.

This article is divided into the following sections:

I. History of evolutionary theory

An understanding of modern evolutionary theory requires examination of ideas that preceded those of Darwin. Some classical Greek philosophers held views that have been thought to have foreshadowed the concept of evolution; but they were abstract speculations not based on objective studies of facts in nature, and, until the 18th century, nobody dreamed of questioning that species had been created as they are.

Early ideas about evolution

The discovery in Java of flying lemurs (colugos, *Galeopithecus*), then regarded as bat-winged monkeys, led the French political philosopher Montesquieu to write in 1721:

> This would seem to corroborate my feeling that the differences between animal species can daily increase and similarly decrease; in the beginning there were very few species and they have multiplied since.

This acceptance of the possibility that species might change into other species was the kernel of the concept of *transformisme*, transmutation, or evolution.

Studies of abnormal or monstrous births and the transmission of striking hereditary traits (especially polydactyly, the possession of extra digits) led a French mathematician, Pierre-Louis de Maupertuis, in 1751 to envisage the multiplication of species as being due to fortuitous recombinations of elementary particles of organisms that lead to offspring deviating from their ancestral forms. This was not only an acceptance of evolution but also a crude attempt to explain it. The French philosopher Denis Diderot, in 1753, added the notion of community of descent:

> If we consider the animal kingdom, and we notice that among the quadrupeds there is none whose physical parts and functions, particularly the internal ones, are not quite similar, may we not readily believe that there was never more than one primeval animal, the prototype of all, while nature only lengthened, shortened, transformed, multiplied, or obliterated some of its organs?

In a monumental work on natural history, Georges Buffon, one of the leading naturalists of the 18th century, raised the question of the possibility that the ass is related to the horse, with which it can breed. He asked if these two species might not, perhaps, have been descended from a common ancestor; but the opposition of the theological faculty of the Sorbonne made him recoil:

> If we once agree that the ass belongs to the horse family, and differs from the horse only because it has degenerated, it could equally well be claimed that the ape belongs to man's family, that the ape is a degenerate man, and that ape and man had a common ancestry.

He went on to consider the possibility that all animals, including ape and man, could be regarded as related, and he answered himself, no doubt with tongue in cheek,

> No, it is certain from Revelation that all animals shared in the grace of Creation, and that each emerged from the hands of the Creator as it is today.

Linnaeus, the founder of modern biological nomenclature, expressed the same orthodox view in his early writings but by 1760 had been driven by his own observations to admit that species could vary. He thought, however, that genera were immutable.

Erasmus Darwin, the grandfather of Charles, by 1794

had concluded that evolution had occurred. He based his conclusion on changes undergone by animals during development (chrysalis into moth, tadpole into frog) and on changes by plants and animals under cultivation and domestication as well as on vestigial organs, crossing, monstrous births, and resemblances in comparative anatomy. He tried to explain evolutionary changes by imagining that desires and aversions, pleasures and pains, led to wants "due to lust, hunger, and danger" and that their satisfaction brought about modifications of species through "the power of acquiring new parts, attended with new propensities, directed by irritations, sensations, volitions, and associations."

Lamarck's inability to distinguish between species

A similar view was reached quite independently by the naturalist Lamarck, who experienced such difficulties in distinguishing between species and varieties that he concluded that there was no real difference between them and that, if enough closely related species were studied together, they merged into one another and differences between them could no longer be made out. In this he is known to have been wrong; however difficult the barrier between species may be to detect, it nevertheless exists. In 1809 Lamarck's views enabled him to propose a system of evolution and to draw up an evolutionary tree, from microanimals to man, with branches indicating community of ancestry between different groups. To explain evolution, Lamarck invoked two factors. The first was a supposed tendency to complexity and perfection (incompatible with the fact of evolution of degenerate forms), which meant that simple organisms alive in Lamarck's time must have arisen recently by spontaneous generation (which was disproved under the conditions of the time by the experiments of an Italian naturalist, Lazzaro Spallanzani, and the French microbiologist Louis Pasteur). His second factor was an imagined *sentiment intérieur*, which, he supposed, caused movements and introduced habits that produced new organs that satisfied the animals' needs. This was an unfounded speculation, and, since Lamarck provided no evidence in support of his views, they found no acceptance. It is perhaps regrettable that the term Lamarckism is not applied to evolution itself. However erroneous, his was the first systematic presentation of the subject. Instead, the term is now taken to describe a theory of the supposed heritable effects of use and disuse of organs ("the inheritance of acquired characters") and the direct action of environmental factors, which Lamarck was not the first to suggest and which are now known not to be inherited.

Georges Cuvier, another French naturalist, rejected evolution because he knew of no fossil forms intermediate between existing species and because 5,000-year-old mummified animals found by Napoleon's expedition in Egyptian pyramids were identical with existing forms. In rock strata of the Paris Basin, the lowest and earliest layers contained fossil faunas "ready-made," which Cuvier attributed to creation; their complete absence from later strata he attributed to catastrophe. He was, however, obliged to accept the fact that the fossils found in upper beds showed an advance in complexity over those in lower beds; this phenomenon, called progressionism, was left unexplained.

Etienne Geoffroy-Saint-Hilaire, who accepted the concept of evolution, was the first to use this word in the modern sense (it earlier had been used to denote embryonic development), in 1831, in a work on fossil reptiles found near Caen, France. In the following year, the British paleontologist Sir Charles Lyell used it in the same sense, although he rejected evolution, because his theory of uniformitarianism (long-continued action of existing geological causes) killed catastrophism, and he mistakenly regarded progressionism as associated with catastrophism.

The contribution of Charles Darwin

Lyell's uniformitarianism acted as an unexpected ferment in the mind of Charles Darwin, who, during the voyage of HMS "Beagle," was led to abandon the orthodox notion of the fixed nature of species and to accept a belief in evolution instead. This change of belief was based on four sets of observations that he had made: the presence in adjacent areas of a continent of related but different species; the similarity of structure between fossil and living forms in the same areas; the resemblance of species on isolated islands to those on the nearest continent; and differences between species on closely adjacent islands of the Galapagos Archipelago in relation to their modes of life and feeding. All these facts, Darwin felt, could be explained only if species were not specially created but had been descended with modification from common ancestral species.

Darwin realized that it would be useless to argue that evolution had occurred unless he could explain how the process itself and, in particular, the adaptations behind it had arisen. He solved this problem in 1838. The details are so closely involved in the process of natural selection that a description of the line of his thought is best deferred until the process itself is considered (see below *Natural selection*). In Darwin's day there was complete ignorance of mechanisms of heredity and of the origin and nature of heritable variation. After constructing his theory in 1838, Darwin remained silent about it for 20 years. During that interval, views favourable to evolution were expressed by others in Switzerland, Scotland, and Austria. Alfred Russel Wallace, working in the East Indies, formed a theory virtually identical to Darwin's in 1858, and papers by the two men were presented at the same meeting of the Linnean Society in 1858. Darwin's *Origin of Species* was published the following year.

It was not until the mid-20th century that a British statistician, Sir Ronald Fisher, and a number of others integrated information from many different areas of biology into a synthetic theory of evolution.

II. The evidence for evolution

The evolution of living organisms has gone on for 3,000,000,000 years, and the 20 years during which Darwin studied the subject before publishing the *Origin of Species* was a ridiculously short space of time for modifications of species to be observed. It must be stressed that Darwin himself never claimed to provide proof of evolution or of the origin of species; what he did claim was that if evolution has occurred, a number of otherwise inexplicable facts are readily explained. The evidence for evolution was, therefore, indirect. Recently, however, direct evidence of evolution has been observed.

Evidence from structural similarities

The indirect evidence for evolution is based primarily on the significance of similarities found in different organisms, which are explicable only if they have derived the features in question, structures or functions, from a common ancestor during descent with modification, for the laws of probability insist that fundamental similarities can be traced only to one single origin.

Comparative anatomy provides the first set of witnesses. There are a quarter of a million different species of flowering plants, but all of them (except for a few parasitic forms) share the basic structures of roots, stem-bearing branches, leaves containing the green pigment chlorophyll, and flowers composed of modified leaves, sepals, petals, stamens, and pistils. They differ in detail between different species, but all are built on the same plan and live in the same way, absorbing salts in water through the roots and fixing carbon dioxide in the green plastids of the leaves in sunshine to synthesize more of their substance. The similarity of plan is easily explicable if all descended with modification from a common ancestor, by evolution, and the term homologous is used to denote corresponding structures formed in this way.

There are over three-quarters of a million species of insects. Despite broad variations in the details of their body plans, they all show a division of the body into head, trunk, and abdomen; they have three pairs of legs and two pairs of wings; and their mouthparts, whether used for sucking or for biting, are built on the same basic plan. In vertebrate animals, the skeleton of the forelimb is a splendid example of homology, in the bones of the upper arm, forearm, wrist, hand, and fingers, all of which can be matched, bone for bone, in rat, dog, horse, bat, mole, porpoise, or man. The example is all the more telling because the bones have become modified in adaptation to different modes of life but have retained the

same fundamental plan of structure, inherited from a common ancestor.

Evidence from development

Embryology provides further examples. The German embryologist K.E. von Baer wrote:

> In my possession are two little embryos in spirit, whose names I omitted to attach, and at the present I am quite unable to say to what class they belong. They may be lizards or small birds, or very young mammals, so complete is the similarity in the mode of formation of the head and trunk in these animals.

Darwin supplied the answer to the problem by showing that this embryonic similarity was due to the inheritance of the structure of these embryos from the embryo of a common ancestor.

Comparative anatomy and embryology present the phenomenon of transformed organs, structures that have changed their form and function with evolution. Among flying insects, the flies (Diptera) differ from most others in having one instead of two pairs of wings. The posterior pair have been modified into gyroscopic organs (halteres) that help in flight. Some fish have utilized the electrical potential of specialized muscles in organs whose electrical discharge is strong enough to serve as a sort of radar emission. The echo, perceived by certain sense organs, enables the fish to sense the proximity of objects in the water. Other fish have increased this function to such an extent that their electric organs are powerful enough to kill or paralyze predators and prey. Only descent with modification can explain the existence of such structures.

Some organs are called abortive or degenerate because they no longer serve a function. The possession of wings by ostriches, which cannot fly, is explicable if ostriches were descended from flying birds, in which the wings were functional. That this is, in fact, the case is evidenced by the structures of the cerebellum, the bones of the wing, and the tail, which show adaptations characteristic of flight. The appendix of man has no useful function, but it corresponds to the cecum of the alimentary canal of herbivorous mammals (and of man's ancestors) in which it is a sac in which bacteria digest the cellulose cell walls of vegetable food. Other examples are the vestiges of hind limb bones in snakes and of teeth in the jaws of young whalebone whales. Some marsupials, mammals that have been viviparous (live bearing) for 100,000,000 years, still show in their embryos vestiges of the egg tooth with which the embryo of the oviparous (egg-laying) ancestor cracked the eggshell.

Evidence from behaviour

Ethology (the study of behaviour) reveals similarities between different species that affirm their community of descent. This is the case, for example, in regard to the instincts in ants, bees, and wasps and to nest building among birds. Thrushes of separate species in Britain and in South America line their nests with mud in the same manner. Hornbills in Africa and in India both plaster up the female in a hole in a tree. In some cases it is possible to discern how instincts evolve. The three-spined stickleback has a complicated ritual of courtship behaviour, which resembles that of the ten-spined stickleback. The latter, however, utilizes simpler components of behaviour, demonstrating the evolutionary origins of the more complex acts performed by the three-spined stickleback.

The chemical characteristics of organisms are no less typical of their species than are their structures, embryonic development, or behaviour. Serology (the study of blood serum) provides evidence of the degree of divergence between the chemical composition of the blood of different animals. Human blood injected into a rabbit makes the latter produce antihuman serum, which, when mixed with human blood, causes clumping and settling (precipitation) of 100 percent of the blood protein. This antihuman serum precipitates blood of other species in the following percentages: gorilla, 64%; orangutan, 42%; baboon, 29%; ox, 10%; deer, 7%; horse, 2%; kangaroo, 0%. These figures serve as measures of chemical resemblance and affinity. It has been shown that seals resemble dogs, and whales resemble even-toed ungulates (*e.g.*, cattle)—results that, expressed as relative degrees of affinity, agree with the evidence from comparative anatomy, embryology, and paleontology.

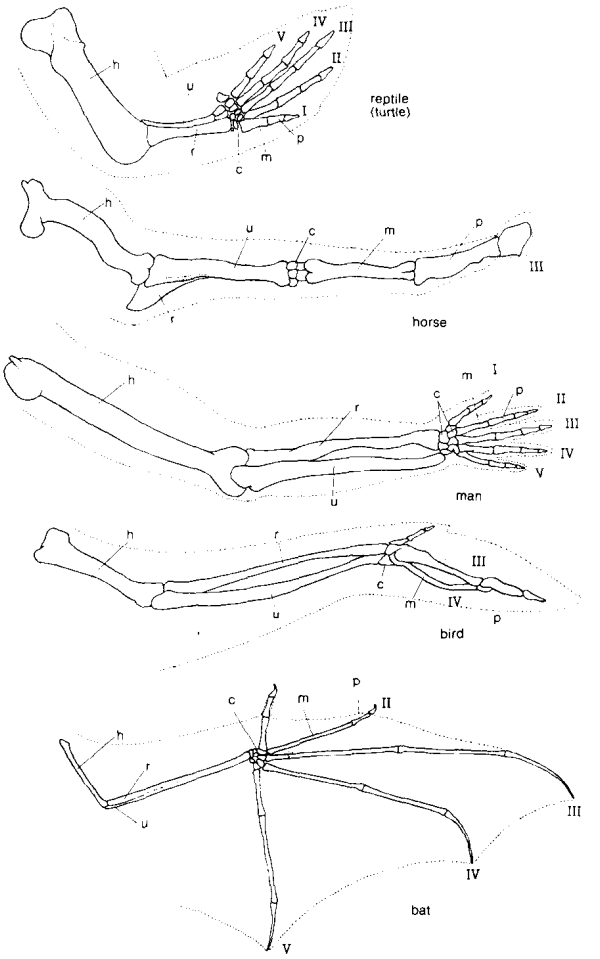

Figure 1: Homologies of the forelimb among vertebrates, giving evidence for evolution. Although the bones correspond, they are adapted to the specific mode of life of the animal. The abbreviations are: h, humerus; r, radius; u, ulna; c, carpals; m, metacarpal; p, phalanx. The Roman numerals indicate corresponding digits.

Biochemical evidence

Biochemistry provides countless further examples of similarities between species, of which one of the most instructive is the structure of the pancreatic enzyme insulin, which is made up of 51 amino acids, arranged in a particular order that varies in details in different related species. At the site where the insulin of cattle has serine, that of sheep has glycine; where insulins of both these species have alanine and valine, insulins of horse and pig have threonine and isoleucine, respectively, The general resemblance of the molecules of insulin in all these species is explicable as due to their descent from a common ancestor; the differences between them are due to adaptation evolved by each species.

An essential constituent of living cells is the protein enzyme cytochrome c, which carries out part of the process of respiration and has the same general chemical structure in bacteria, fungi, plants, and animals, but with differences in the arrangement of some of its constituents. The degrees of these differences make it possible to classify the organisms, in accordance with their evolutionary positions, into a phylogenetic tree (a diagramatic indication of evolutionary pathways). Assuming a fixed rate at which changes occur in evolution, it has been possible to calculate the time elapsed since the different forms of cytochrome c diverged from a common ancestor. In other words, the time lengths of the branches of the phylogenetic tree can be estimated.

The above results throw a new light on an old branch of biology: systematics, which is concerned with classification (see CLASSIFICATION, BIOLOGICAL). The basic biological unit in which organisms exist is the species; but species are not casually distributed as grains of sand on a beach or fancifully assorted as imaginary constellations

in the sky. Rather, species fit naturally into successively larger groupings: genera, families, orders, classes, and phyla. As more is known about individual species, the groupings make sense only if they are based on the natural pattern of the evolution of these species from common ancestors.

Evidence from parasitology

The study of parasites provides further evidence of evolution. Most parasites have retained evidence of their specialization from an ancestral, free-living form, from which they evolved by becoming adapted to live on, in, and at the expense of other living organisms, losing organs essential for living a free life. Biologists recognize that, to support the view that species did not evolve but were created, it would be necessary to conclude that man was created with poliomyelitis virus in his nerve cells, malaria parasite in his blood, and tapeworms in his intestines.

Parasitology provides yet another line of evidence. Internal parasites (and external ones that live under a layer of fur or feathers) inhabit a constant environment, a condition under which evolution may proceed slowly. But the hosts harbouring the parasites live in a changing external environment and may have evolved fast enough for the relationships between them to have been obscured by structural changes. The affinities between the grossly different hosts may sometimes be elucidated from the affinities existing between their parasites. Thus, pythons have certain internal parasites similar to those of monitor lizards, and pigeons have feather lice similar to those of parrots. *Herpes simplex* virus is found only in man and monkeys and lice of the genus *Pediculus* only in man and chimpanzee. In all these cases, the presence of closely related parasites confirmed the existence of relationships established by structural comparisons.

Biogeographical evidence

The geographical distribution of plants and animals was first studied by Buffon, who noticed the differences in flora and fauna between America and the Old World. Buffon's studies provided Darwin with some of the questions that led him to abandon belief in the fixity of species and creation. He wondered why the fauna of Cape Verde Islands has an African composition while that of the Galapagos Islands has South American characteristics. These similarities could be explained only by the evolution of Cape Verde species from African ones and Galapagos species from South American ones. The mechanism now understood for the origin of species makes it certain that each species originated only once and in only one area. There are many forms whose modern geographical distribution is discontinuous; for example, tapirs, now limited to South America and the East Indies. Lungfish are found only in South America, South Africa, and Australia. In each case, the distribution can be explained easily if the animals dispersed from the region where they originated and subsequently became extinct in intermediate regions. Extinct animals can often be found as fossils; fossil tapirs have turned up in North America, Asia, and Europe, and fossil lungfish have been found even more widely.

Evidence from paleontology

Paleontology occupies a key position in evolutionary studies; the fossils in the earth's crust are objective evidence of the course taken by living organisms in their evolutionary history, or phylogeny (see PHYLOGENY). By themselves, fossils do not "prove" evolution, for it could be argued that they had all been specially created and then succumbed to catastrophes, as Cuvier believed. But such a view fails altogether to explain why the fossil forms in lineages studied on sufficient material fall in obvious series; nor does it explain why the feet, teeth, and body sizes of fossil horses are so closely correlated with the successive and different climatic conditions of their environment.

With the help of radioactive dating of the deposits in which they lie, it has been possible to determine the absolute ages of the fossils and to measure the rates at which different groups have evolved. The data are still approximate, but they provide an estimate of the dimensions of the fact and pageant of evolution and of its problems.

The earliest evidence of life in the crust of the earth does not always consist of organisms themselves but may be found in chemical substances that are the result of the life of organisms, such as layers of oxidized iron and other chemical "fossils." In the atmosphere, the two stable isotopes of carbon, carbon-12 and carbon-13, are in a ratio of 99 to 1. Photosynthesis carried out by organisms, using sunlight energy, converts carbon dioxide into organic carbon compounds with a higher ratio of carbon-12 to carbon-13 than is found in ordinary rocks, thus indicating the former presence of living organisms, as in the Fig Tree deposits in Rhodesia, about 3,000,000,000 years old, in which traces of structure of bacteria and blue-green algae have been found, some surrounded by concentric layers of limestone secretion. Undoubted stalked bacteria and blue-green algae have been discovered in the Gunflint iron deposits of Ontario, nearly 2,000,000,000 years old. In the Bitter Springs Cherts of Australia, 1,000,000,000 years old, true green algae and fungi have been recognized. The oldest known fossil animal is an already well-developed wormlike form, *Xenusion*, 800,000,000 years old, from the Precambrian of Sweden. The first animals must have been soft and incapable of preservation as fossils. When the Cambrian Period began, 600,000,000 years ago, many forms of algal plants and invertebrate animals were already developed.

Genetic evidence

It would require very special pleading to pretend that paleontology does not present objective evidence for evolution, but more direct evidence is now also available, first from cytogenetics. In long chromosomes of the fruit flies of the genus *Drosophila*, the genes in one species form a linear series that may be labelled ABCDEFGHI. In another species, the corresponding genes are in the order AEDCBFGHI; the section BCDE has been inverted. A third species has the order AEHGFBCDI; here the section DCBFGH of the second species has been inverted, which indicates that the third species was derived from the second, and it from the first.

III. The process of evolution

NATURAL SELECTION

Evolution is the product of improvement in adaptation, and it was adaptation that Darwin felt that he must explain before he could convince anyone of the fact of evolution. The logical approach to the principle of natural selection, therefore, begins with a consideration of adaptation.

Adaptation is a word with two meanings, one referring to a process and the other to its product. It is the biological process by which advantage is conferred on those organisms that have structures and functions enabling them to cope successfully with the conditions of their environment. The ecological position occupied by an organism, relative to the entire range of environmental variables, is called the niche. The word adaptation is also used to denote those structures and functions specialized for a particular role.

All living organisms are adapted to their modes of life in a general way, and each is adapted to the characteristics of its own niche. A plant depends on its roots, by which it absorbs water and inorganic salts in solution and by which it is anchored; it requires a stem, balanced by the geometrical distribution of its branches, as a result of which the plant is able to maintain a vertical position and support its leaves; and the leaves, in turn, are vital as sites of photosynthesis, the process whereby the energy from the sun is used to synthesize organic chemical compounds.

In addition to the general adaptations, which are common to all species in large groups of related organisms, there are also special adaptations that some species have and others lack, and it was for an explanation of the origin and cause of these adaptations that Darwin looked. A woodpecker, for example, possesses the gross adaptations common to flying birds: feathers, wings, beak, clawed, scaly feet, etc. As adaptations for subsistence on insect grubs hidden under the bark of trees, the typical woodpecker has four structures that make its search for food more efficient: two toes on each foot are turned backwards (instead of the usual one), enabling the bird to

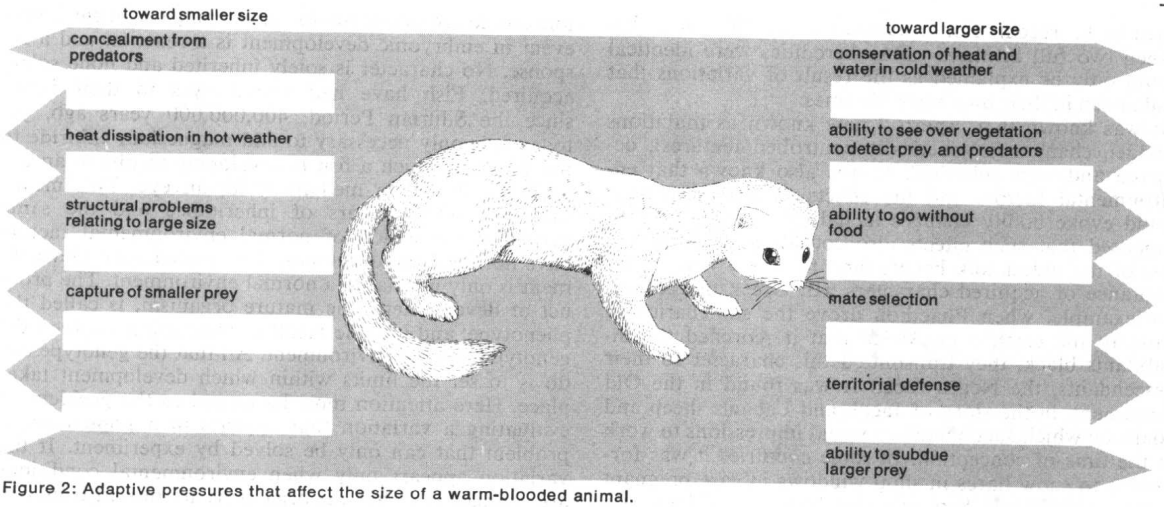

Figure 2: Adaptive pressures that affect the size of a warm-blooded animal.

get a firm foothold on the bark of the tree; the tail feathers are stiff and serve to prop the bird in position while it bores; boring and flaking are done by a stout and strong beak, with which a hole is chiselled through the bark and into wood; finally, an exceptionally long tongue enables the bird to take the insects at the bottom of the holes. Among woodpeckers, each species has further specializations that adapt it to its own segment of the bark-foraging niche.

Another example is mistletoe, any of about 80 species of parasitic plants (the familiar species being in the genera *Phoradendron* and *Arceuthobium*) that live intimately spliced onto branches of trees, from which, not having true roots, the mistletoe obtains water and salts in solution while the chlorophyll in its green leaves enables it to carry on photosynthesis. In order to survive, mistletoe is dependent on three factors: an insect to pollinate its flowers; a bird to disseminate its seeds by eating the berries and depositing them with its droppings on the branches of suitable trees; and an appropriate tree on which the parasitic relationship can be established. These adaptations are held to have arisen from natural selection of heritable variations.

The change that can be achieved through selective breeding of parents possessing particular characters has been known since the Neolithic Period, when man began to cultivate plants and domesticate animals, increasing their size, yield, and other desired qualities. In Darwin's thinking, an important example of selection working on heritable variation was the comparison between wild bison (*Bison bison*) and Indian domestic cattle (*Bos indicus*) with humps, for the structural differences between them would certainly be recognized as of the value at least of separate species if they were found in nature, and one of them was not the result of artificial selection by man. Darwin was sure that the cause of change was selection and that those organisms that were better fitted to withstand the struggle for existence, which goes on everywhere, would prosper and perhaps oust those less well fitted. But how such a system of selection could operate in nature, long before any man was there to supervise it, baffled him until 1838, when he read English economist Thomas Malthus' *An Essay on the Principle of Population* and happened on the statement that, since human population, if unchecked, would increase in geometrical progression and double in 25 years while food supply increased only in arithmetical progression, famine, misery, and mortality constantly threatened the human race, and particularly its poorer classes.

Darwin saw that, since plants and animals are quite unable to increase their food supplies artificially, the principle of mortality automatically imposed by nature would apply to them in full force. Natural selection was entirely Darwin's idea, not derived from Malthus. The latter's theory of human population limitation did not take into account the great increases in per-acre food production made possible by modern agricultural techniques and, therefore, requires modification in order to be entirely valid. It is, however, valid when applied to organisms in nature, and it explains how selection works in nature, in its most direct form, by killing the insufficiently adapted. Hence the term natural selection.

The mechanism of natural selection

The basic principle of natural selection is fairly simple. Most organisms produce more offspring (eggs, seeds, or young individuals) than live to maturity. The number of individuals in most species remains more or less constant from year to year. There must be, therefore, a high rate of mortality (from starvation, predation, disease, malformation, and accidents of the physical environment), eliminating individuals at various stages of their lives: as eggs, embryos, larvae, juveniles, and adults. Within a population, individuals are not identical but show variation that may affect any character, structure, or function at random. Some variations have characters that allow their possessors to function more efficiently in the struggle for existence than those that lack these characters. In other words, they are better adapted, even by ever so little, to the conditions of their ecological niches. They live longer, leave more numerous and healthier offspring, and provide the majority of the parents of successive generations. Heredity ensures the resemblance between parents and offspring. By natural selection of heritable variation, successive generations will maintain and even improve on the degree of adaptation achieved by their parents.

Adaptations thus confer survival and reproductive value on their possessors, and the ecological conditions of the environment determine at every stage which variations are adaptive and which not. Natural selection therefore rams better adapted variants into their ecological niches under pressure and ejects other variants, thereby providing more available, unoccupied niches. The case of the woodpecker is explained by random variations in the foot, tail feathers, beak, and tongue, selected in the direction seen. It is relatively simple, but the same principle is involved in the complicated cases of parasites, such as malaria or tapeworm, both of which involve the interposition of an intermediate host (mosquito or fish) in the life history.

VARIATION

Primitive views on variation

Darwin never tired of repeating that without heritable variation natural selection could do nothing at all, and there would be no evolution. But neither Darwin nor anyone else at the time the *Origin of Species* was published had objective knowledge of variation, its nature and its origin, or of heredity. It was known that variation existed, and the only hypothesis then available was that of "blending inheritance," by which it was supposed that offspring struck an average between the characters of their parents. This meant that, at each generation, variance was halved and that after ten generations all variations would have been levelled off and obliterated. This meant, in turn, that the numerous observed variations would

have to be recent. For instance, all the differences between two full brothers whose heredities were identical could only be explained as the result of variations that had arisen in their own early lifetimes.

It was known that "sports," now known as mutations (sudden changes in genetically controlled features), occurred and were inherited. It was also known that environmental factors and the effects of use and disuse could evoke bodily changes in individuals. It was then supposed that such effects also could be inherited, for one of the oldest folk beliefs (and fallacies) was the inheritance of acquired characters. (In Greek mythology, for example, when Phaethon drove the sun-chariot so close to the earth over Africa that it scorched the inhabitants black, they transmitted this character to their descendants, the Negro race.) It was found in the Old Testament, in the story of Jacob and Laban's sheep and goats, on which Jacob induced visual impressions to work at the time of conception. In some countries it was forbidden to show hares in shop windows in case pregnant women should see them and give birth to children with harelips.

In spite of faked results and the neglect of proper precautions in experiments, no case whatever is known of the inheritance of any modified character impressed on the body of a multicellular organism by the effect of the environment or use or disuse of organs. The proviso of multicellularity is necessary because in the reproduction of unicellular organisms, when the parent divides, part of its body (on which the environment may have induced a modification) passes straight into the bodies of the offspring, which may still show the environmental effect. This is not what is meant by inheritance, which results only from the transmission of genetic material in reproductive cells.

Mendelian genetics

The Moravian monk Gregor Mendel filled the gap in Darwin's scheme in 1865, when he showed that characters are controlled by particles, now called genes, which exist in pairs (alleles), one member of each pair derived from each parent. He demonstrated that the particles do not become contaminated but remain pure and separate (segregate) at germ-cell formation, so that not more than one of each pair enters any one germ cell, and that they recombine at random at fertilization. At each cell division, genes copy themselves exactly but occasionally undergo sudden changes (mutations), after which they continue to copy themselves exactly in their changed state until they mutate again.

A further important fact discovered by Mendel was that some genes are stronger, more penetrant, than others and can make their effects visible in the offspring when such genes are inherited from one parent only—that is, are present in "single dose"; such genes control dominant characters. The weaker genes can manifest themselves in offspring only if inherited from both parents—that is, in "double dose"; such genes are called recessive, and when one is present in an organism paired with its dominant allele, its effects are hidden.

Mendel's work was ignored until 1900, when it was rediscovered. During the first 20 years of the present century, it was confirmed completely by a number of workers who showed that genes are carried in linear order in the chromosomes, which are visible in the nucleus at division. Genes carried on different chromosomes segregate at random exactly as required by Mendel's system, but genes carried on the same chromosome show "linkage" and are transmitted together unless the chromosome undergoes "crossing-over," when the linked genes become separated and segregate. The mechanism of the chromosomes provides exactly what is required to explain the distribution of Mendelian genes.

Genotype and phenotype

To understand the role of inheritance in evolution, it is necessary to consider the relation between genetic transmission of factors (genes) and embryonic development of expressed characters, for it is only through embryonic development that characters arise at all. The genes of the organism, inherited from its parents, constitute its genotype, which determines and limits its capacity to respond to normal and abnormal environmental factors and to factors within the developing organism. Every event in embryonic development is a reaction and a response. No character is solely inherited and none solely acquired. Fish have had paired eyes in their heads since the Silurian Period, 400,000,000 years ago, yet today it is only necessary to add magnesium chloride to the water in which a fish is developing to obtain an abnormal fish with a median cyclopian eye. This means that 400,000,000 years of inheritance and the same period of the action of normal environmental factors have not fixed the development of paired eyes. Development is only normal in a normal environment. The product of development, the mature organism, is called the phenotype, and it is the result of interaction between the genotype and the environment. All that the genotype can do is to set the limits within which development takes place. Here attention must be turned to the problem of evaluating a variation that appears in a population, a problem that can only be solved by experiment. If the variation appears only when environmental conditions are changed (as when the organisms are moved from one climate to another or when the diet is changed) and disappears when the original environmental conditions are restored, the variation is nonheritable. It has not been incorporated into the genotype and is known as a modification or phenotypic variation. If the variation arises without any change in environmental conditions and continues to appear in the offspring, it is heritable and is known as a mutation or genotypic variation. Only genotypic variation provides heritable variation on which evolutionary change can be based; but the ability of an organism to undergo nonheritable modification in response to environmental factors may "cushion" it against some of the rigours of natural selection, and this ability itself may be genetically controlled.

Mutation is therefore the inception of heritable variation. It may affect only a single gene, as a result of imperfect replication of the molecule of deoxyribonucleic acid (DNA), of which the gene is composed, or it may affect whole chromosomes by duplicating one or more of them as extras, following imperfect cell division. In man the presence of one supernumerary chromosome is responsible for the serious disorder mongolism. When the complete set of chromosomes is increased two, three, four, or more times, the resulting condition, polyploidy, can play an important part in speciation in plants by producing genetic isolation between populations.

In addition to genotypic variation there is a category of "nongenetic" inheritance due to structures present in the extranuclear (cytoplasmic) part of the reproductive cell or fertilized egg. Such cytoplasmic transmission therefore does not involve Mendelian genes in chromosomes and is solely maternal, for the sperm has no cytoplasm. An example is the inheritance by plastids or plasmagenes (small bodies in the cytoplasm) that can be seen in some plants whose branches, normally green, change to white, and seeds from flowers born on such white branches give solely white plants. This type of inheritance does not have much potential for evolutionary change.

THE SYNTHETIC THEORY OF EVOLUTION

The evolution of dominance and recessiveness

Even when Mendel's work was first rediscovered and was still imperfectly understood, it caused great controversy. On one side Mendelian geneticists maintained that their mutations were the only source of heritable variation and that their new characters appeared, ready-made, without any previous selection. The Darwinian selectionists objected that mutations were deleterious, if not pathological, that the sudden changes that they caused were incompatible with the slight gradual changes that Darwin's theory required, and that mutations, which bore no relation whatever to environmental conditions, were utterly incapable of explaining the origin and improvement of adaptation to those environmental conditions.

Such was the state of evolutionary studies when an English statistician, Sir Ronald Fisher, observed that the great majority of mutations controlled characters that were both recessive and deleterious and concluded that they were recessive because they were deleterious—in

other words, that they had become recessive from a previous condition intermediate in character. That this view was correct was shown by experiments in which it was clear that the action of any one gene in controlling its character is itself under the control of the other genes, which form what is called the gene complex. The composition of the gene complex is constantly reshuffled at every fertilization when the segregated genes recombine at random. If a deleterious mutation appears, those gene complexes that reduce the effect of that mutation give survival value to their possessors; possessors of gene complexes that do not do this perish. This explains the remarkable situation of the dominant "eyeless" gene in the fruitfly (*Drosophila melanogaster*), a gene with obviously deleterious effects. Some individuals with "eyeless" genes can breed, but there is great mortality in the offspring. It is possible to establish a pure eyeless strain by careful maintenance of the breeding colony. If such breeding is continued for a few generations, flies are eventually produced that possess normal eyes. This does not mean that there has been any contamination of the eyeless gene, as is proved by crossing such genotypically eyeless (but phenotypically eyed) individuals with other individuals of the original wild type (the normal gene complex). The offspring of such crosses show the eyeless effect of the gene in all its original virulence. During the generations of breeding eyeless flies, there has been reshuffling of the gene complex at each generation with heavy mortality, but some gene complexes have obliterated the deleterious effects of the eyeless gene. This selection of gene complexes received experimental proof when the English geneticist E.B. Ford, studying the currant moth (*Abraxas grossulariata*), selected the same gene in opposite directions, making it dominant in one line and recessive in the other.

When one gene of a pair of alleles becomes recessive, the other necessarily becomes dominant, which is why the genotype of the "wild type" of organism found in nature contains so many dominant genes that mask recessives. These recessive genes are a contingency reserve for possible future use, any of which may be favoured by selection when conditions change, as they always do, unpredictably.

The relative importance of selection and mutation

The rates at which mutations of genes occur in nature have been estimated in organisms as diverse as bacteria, maize, flies, and man and found to be of the order of once in each gene pair, in each generation, in 500,000 individuals. This rate can be increased by physical and chemical mutagenic agents (X-rays, mustard gas, etc.), and in some cases the rate is itself subject to genetic control. In nature it is a slow rate, but it builds up into a stock of genetic diversity that supplies the heritable variation on which natural selection works.

The astronomical quantities of potential variation that can be produced by the Mendelian mechanism of segregation and recombination of genes is shown by Mendel's own example of the number of different genotypes produced in two generations when parents differing in only seven pairs of genes are mated; the number is 2,187. As the numbers of genes in higher organisms run into thousands, the number of genotypes resulting from their segregating and recombining at fertilization is three raised to the power of the number of differing genes. More heritable variation could be produced than ever is actually produced. This is the solution to the difficulty imposed on Darwin solely by the errors of the notion of "blending inheritance," the problem of accounting for a sufficient supply of heritable variation for natural selection to work on. Mutation maintains variation, while "blending inheritance" would annihilate it.

If mutations took place more frequently than they do, variants would be lost before natural selection had had time to derive from them what potential advantages they might present. Mutation not only need not but must not be too frequent.

Fisher's researches showed that the system of Mendelian genes that mutate occasionally, segregate, and recombine at random provides exactly the mechanism required to explain evolution by natural selection. They showed that if the majority of mutant genes are recessive because they have become recessive, one may conclude that natural selection has acted against them (under the conditions that existed when they mutated). There is no "favourable breeze" of mutations, nor are mutations directed in any advantageous sense. When they first occur, mutations are not adaptive. This demonstration of the initial suppressive effect of natural selection on mutants means that all theories that include the concept directed variation (Lamarckism, program fulfillment, orthogenesis, providental guidance, and others) and that seek to explain evolution as a result of control of the direction in which mutation occurs, whether by supposed effects of use and disuse, satisfaction of needs, environmental factors, inherited "memory," or "inner urges," are contradicted flatly by the observed fact that natural selection acts against new mutants.

Mutation, at the rates at which it occurs, is quite incapable of establishing a character in a population if there is the slightest degree of selection exerted against it, and the forces of selection, or selective pressure, can be measured. The short-term effect of mutation on evolution is therefore minimal or nil. It has been calculated that previous mutations have already set up such a stock of potential heritable variation that if mutation were to stop altogether today, evolution would go on from now as far into the future as it has come in the past. It is selection, not mutation, that controls the direction, rate, and intensity of evolution. This conclusion, based on experiments in genetics, is confirmed from work in paleontology.

The way in which the character of organisms are affected by environmental changes is well illustrated by the evolution of the horse (Figure 3). At the start in Early Tertiary times (about 65,000,000 years ago), the habitat of the ancestral horses was swampy and the vegetation luxurious with leafy plants. To this environment the horse's ancestors (*Hyracotherium*) were adapted by feet with four splayed toes that did not sink in the mud and short teeth for browsing on and eating the soft leaves of trees and shrubs. Later, in the Miocene, the vegetation in many areas changed to grass, which contains silicon and would wear down short teeth. The horse's ancestors (*Merychippus*) then became adapted to this food by the evolution of long high-crowned teeth, capable of uninterrupted growth. At that time the ground was dry and hard, and the number of toes in the feet became reduced, finally to one, with a hoof and a spring joint. These animals were thus able to exploit the grassland niche, as it became more prevalent.

The evolution of the horse was never in a straight line. First many-toed, low-crown toothed browsers changed

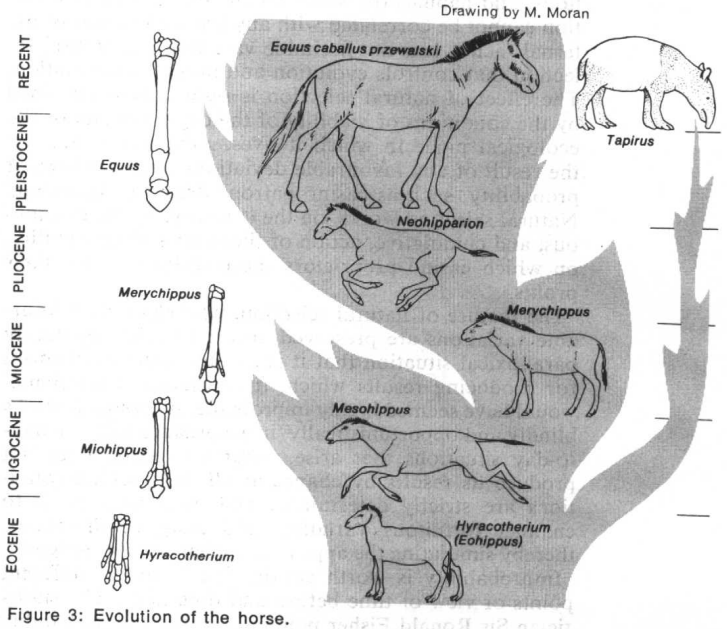

Figure 3: Evolution of the horse.