composition in a single, continuous feed process. Water-soluble monomers are frequently incorporated in latexes to generate surfactant, during the course of the reaction, which will be physically grafted to the surface of the polymer particles. Unlike conventional surfactants, these will not separate from the particle surfaces on freezing or shearing to give particle coagulation, nor will they diffuse out of the formed films into the surrounding environment.

Core-shell particles, in which a softer outer shell [for example, poly(butyl acrylate)] may give good film formation, while a harder core [for example, poly(methyl methacrylate)] provides strength, can be prepared by a two-stage controlled monomer feed.

The most rapid advances in emulsion polymerization in the near future are likely to arise from application of the methods of controlled radical polymerization (CRP). Reversible addition fragmentation chain transfer (RAFT), atom transfer radical polymerization (ATRP), and nitroxide-mediated radical polymerization have been used recently on the laboratory scale to give control of molecular weight and allow formation of novel block copolymers in emulsion polymerization systems. These methods use a reversible capping of the growing polymer radical to greatly reduce termination processes. Rather than the few growing chains of very short lifetime of conventional free-radical polymerization, CRP gives many (slowly) growing chains of very long lifetime. This leads to a much narrower distribution of molecular weights and the ability to create a range of polymer such as blocks and combs. Recent work suggests the practicality of eliminating all surfactant from emulsion polymerization through use of an aqueous-phase RAFT agent, and being able to make polymer chains of any desired architecture (**Fig. 5**). In the first stage, a "living" (termination-free) aqueous-phase polymer is generated, which reacts with the hydrophobic monomer added in the second phase to form polymeric surfactant molecules. These form rigid micelles which grow into polymer particles by continued feeding of the hydrophobic monomer. It has been suggested that because the individual polymer molecules in such a system are irreversibly attached to the micelles, unlike conventional surfactants which undergo rapid exchange, the number of micelles originally present can be correlated directly to the number of polymer particles. Thus any desired polymer microstructure can be built up. These methods also provide a pathway for incorporating specific functionalities on the surface of a polymer particle, for instance, to attach antibodies for use in latex agglutination tests in biomedicine. *See* CONTROLLED/LIVING RADICAL POLYMERIZATION; MACROMOLECULAR ENGINEERING.

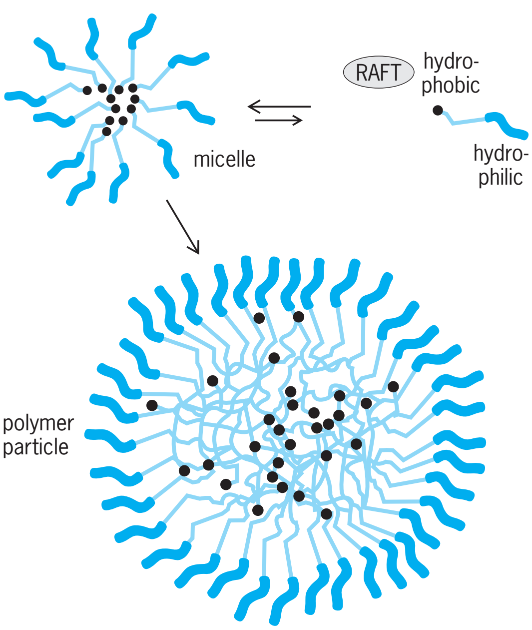

Fig. 5. Amphiphilic RAFT in emulsion polymerization.

Robert G. Gilbert; Christopher M. Fellows

Bibliography. C. Burguiere, C. Chassenieux, and B. Charleux, Characterization of aqueous micellar solutions of amphiphilic block copolymers of poly(acrylic acid) and polystyrene prepared via ATRP: Toward the control of the number of particles in emulsion polymerization, *Polymer*, 44:509–518, 2002; C. J. Ferguson et al., Effective ab initio emulsion polymerization under RAFT control, *Macromolecules*, 35:9243–9245, 2002; R. G. Gilbert, *Emulsion Polymerization: A Mechanistic Approach*, Academic Press, London, 1995; K. Matyjaszewski, New (co)polymers by atom transfer radical polymerization, *Macromol. Symp.*, 143:257–268, 1999; M. Vicente et al., Control of microstructural properties in emulsion polymerization systems, *Macromol. Symp.*, 182:291–303, 2002.

Enantiornithes

An extinct and specialized group of land fossil birds that lived during the Cretaceous Period. Enantiornithes represents the most diverse avian group in the Mesozoic. This group was not discovered until 1981, at which time some very unusual, isolated bones from the Late Cretaceous of Argentina were recognized as belonging to a new group of birds. Enantiornithine birds are now known to be widely distributed, with remains from Argentina, North America, Mexico, Mongolia, Australia, Spain, and China. Because their anatomy includes a mixture of specialized and primitive features, they are thought to represent an evolutionary side branch in early avian evolution that became extinct at the end of the Cretaceous and left no living descendants. *See* AVES; CRETACEOUS; FOSSIL BIRDS; MESOZOIC.

Characteristics. Enantiornithine birds are readily distinguishable from living birds. The most notable characteristic is the articulation between the scapula (shoulder blade) and coracoid (a bone connecting the scapula and the sternum). In enantiornithines, the scapula has a fossa for articulation with a process on the coracoid, whereas modern birds have the opposite arrangement in which the coracoid bears the fossa and the process is found on the scapula.

***Protopteryx*, the most primitive known enantiornithine bird, collected from the Early Cretaceous of Hebei Province, northern China.**

The group name refers to this difference: the Greek word "enanti" means directly opposite, and therefore Enantiornithes means "opposite birds." Enantiornithes is a natural (monophyletic) group, which is united by the shared possession of several unique features, including the characteristic contact between the scapula and coracoid, the distal (lower) end of the third metacarpal of the hand extending markedly past that of the second metacarpal, and a furcula (wishbone) with a long process (hypocleidium) that projects forward.

Enantiornithine birds were good fliers, possessing a more advanced flight apparatus than *Archaeopteryx*, including a short skeletal tail (comprising a few free vertebrae and a pygostyle or "parson's nose"), a sternum with a keel, and a wing that was generally similar to that of modern birds. Enantiornithines also possessed asymmetric flight feathers and the alula (bastard wing), indicating that they had acquired sophisticated flight capability. Conversely, some primitive avian characters, such as the presence of toothed jaws, were retained in many enantiornithes (although at least one form, *Gobipteryx* from Mongolia, completely lost the teeth). Primitive features were also retained in such structures as the pelvis and foot of enantiornithines.

Fossil record. Enantiornithine birds were initially described on the basis of often fragmentary Late Cretaceous forms such as *Enantiornis*, *Alexornis*, and *Gobipteryx*. However, the recognition of more complete Early Cretaceous enantiornithines has allowed significant progress to be made in our understanding of these birds during the last decade. Early Cretaceous enantiornithines have been discovered in Spain, China, Australia, and Russia. These early forms are generally small—much smaller than other contemporaneous birds such as *Confuciusornis* and *Jeholornis*. The proportions of the hindlimbs and toes, and the presence of large, curved toe claws, indicate that enantiornthines were mainly arboreal forms. Most enantiornithines, such as *Protopteryx* (see **illustration**), probably fed on insects. However, there are some exceptions: for example, *Longipteryx* (from the Early Cretaceous of China) had an elongated beak, rather like a living kingfisher, which suggests that it ate fishes (although in the case of *Longipteryx*, densely packed teeth were also present). Another Chinese Early Cretaceous enantiornithine, *Longirostravis*, probably had a probing feeding behavior. Discoveries of hundreds of specimens of Early Cretaceous enantiornithines from northeastern China (referable to 12 genera) have shown that by this time Enantiornithes had significantly differentiated not only in morphology, size, and flight capability but also in terms of dietary adaptation. *See* CONFUCIUSORNITHIDAE.

Zhonghe Zhou

Bibliography. L. M. Chiappe and C. A. Walker, Skeletal morphology and systematics of the Cretaceous euenantiornithes (Ornithothoraces: Enantiornithes), in L. M. Chiappe and L. M. Witmer (eds.), *Mesozoic Birds above the Heads of Dinosaurs*, pp. 240–267, University of California Press, Berkeley, 2002; A. Feduccia, *The Origin and Evolution of Birds*, 2d ed., Yale University Press, New Haven, 1999; L. D. Martin, The origin and early radiation of birds, in A. H. Bush and G. A. Clark, Jr. (eds.), *Perspectives in Ornithology*, pp. 291–338, Cambridge University Press, 1983; C. Walker, New subclass of birds from the Cretaceous of South America, *Nature*, 292:51–53, 1981; Z. Zhou, The origin and early evolution of birds: Discoveries, disputes, and perspectives from fossil evidence, *Naturwissenschaften*, 91:455–471, 2004.

Encalyptales

An order of the true mosses (subclass Bryidae) that grow in dull, dark tufts on soil or soil-covered rock, generally in calcareous areas. The Encalyptales consist of a single family and two genera, the better known being *Encalypta*, the extinguisher moss, so called because of its long calyptra of candle-snuffer form. The leaves resemble some of the Pottiales in shape and papillosity, but the ladderlike thickenings of the basal cells and the peristome characters indicate a fairly distant relationship.

Encalyptales are characterized by broad, papillose leaves and erect capsules covered by very long calyptrae. The stems are erect and simple or forked with folded, incurved leaves. Leaves are broadly acute to rounded and often abruptly short-pointed to