Morals (Morchella) attracted the attention very early as a choice article of food. It was constantly looked for in the mycological forays in many countries especially in France and Britain. Though some attention was given to the taxonomy of morals yet on the whole literature on nutrition, biology and related aspects is rather meagre. Literature review bearing on the present investigations is being presented under the following sub-heads:

Cultivation

In view of the gastronomic excellence of edible mushrooms and hazards involved in using collections from wild sources, a number of attempts have been made from early times to bring these into cultivation. Though three to four species of mushrooms only have passed into wide commercial cultivation in different parts of the world, attempts at cultivation of many others have been made. The earliest endeavours appear to have had, for their purpose, an artificial reproduction of the natural conditions under which the particular fungus grows.

Greeks and Romans appear to have known a method of growing Pholiota aegerita on stumps of black poplar, which was probably the first fungus to be brought into cultivation (Suller, 1915 & Rolfe and Rolfe, 1925). The observations made early that certain edible mushrooms prefer charred
spots or stumps was utilised in growing *Polyporus corylius* on artificially charred stumps or logs of some trees (Wolfe & Wolfe, 1925). The first scientifically planned experiments on the cultivation of edible mushrooms were started by J. Costantin and L. Matruchat as early as 1883 in France (Costantin, 1936). Besides the studies on *Agaricus bisporus*, they collaborated on the study of a number of other mushrooms such as: *Tricholoma nudum*, *Morchella esculenta*, *Amanita rubescens*, *Lentinus procerus*, *Marasmius crenatus* and *Hydnum coralloides*. They were successful in cultivating *Tricholoma nudum* on beds of various materials, amongst which fermented beech leaves were the best on which fruit bodies were obtained after six months in the caves (vide Ramsbottom, 1963). Singer (1961) reviews the experiments on the commercial cultivation of this species (*Lentinus nudus*) and is of the opinion that the long incubation period - a two year cycle of production, is a discouraging feature. Singer (1961) has also surveyed the whole field of cultivation prospects and possibilities of other edible mushrooms.

The earliest method of Morel cultivation has probably been mentioned by J. G. Gleditsch in 1753 (vide Ramsbottom, 1953). The country women of Neo Marchia (Mark Brandenburg) while gathering morels having noticed that they were abundant in burnt places, made fires to encourage their appearance. These practices, however, had to be forbidden as it resulted in forest fires sometimes. McCubbin (1913) and Krieger (1936) have also recorded the abundance of morels in burnt over areas. Duggar (1915) and Rolfe &
Rutge (1926) are of the opinion that cultivation of morels offer promising possibilities and latter mentions of a method in which morels were cultivated in France on beds prepared on similar lines to those obtaining for _Agaricus bisporus_, sown with cut morels, though not with significant success. Though Costantin and Matruchot were the first to start experiments on the cultivation of _Morchella esculenta_ yet Yvoire (1889) was the first to set forth a method for morel cultivation. The method probably taking advantage of earlier observations of Roze (1883) that _M. esculenta_ was found parasitizing the rhizomes of Jerusalem artichoke–_Helianthus tuberosus_, involved their use. The method also recommended by Heim (1936) has been outlined by Baker & Matkin (1959); a loose moist soil in which Jerusalem artichokes were growing was inoculated in May or June with fragments of fresh or dried morels. It was watered 4 to 5 times during the summer with dilute potassium nitrate. In the fall non-fermented apple pomace was placed around the artichoke plants to a depth of 1 cm, and covered 1 to 2 weeks later with dry leaves of hornbeam, chestnut, beech, oak or ash and twigs were placed on top. In April or May the twigs and leaves were carefully removed and the area shaded with a cloth. A yield of 300 morels was obtained in an area of about 100 square feet.

Subsequently Repin (1901) got fruiting bodies around a bed composed of dry leaves rendered alkaline with sodium carbonate and in a trench in which apple residue had been
deposited. He also established that the morel does not necessarily grow parasitically on roots of trees and can grow saprophytically.

Molliard (1904, 1906) carried out systematic studies on Morelless. He obtained conidial stages of Morelless esculenta var. rotunda, M. Conica and M. deliciosa on a compost of organic substances and identified it as belonging to the genus Costantinella, in the first instance. Subsequently he conducted a number of experiments on the cultivation in pots and open near Fontainebleau as well as in the greenhouse of Botany Department of the Sorbonne. In his experiments he made use of his observations that morels often grow on apple residues and paper waste. He made a bed of alternate layers of apple residue and paper waste in open ground under cherry trees, covered with kneedeep earth and obtained important output of Morels - Morelless esculenta, on spawning. He repeated the experiments with Morelless hortensis, a rare morel of that area and was successful too.

Costantin (1936) has reviewed Molliard's work and has published pictures of fruiting bodies obtained in culture. He also records a yield of 350 g per square metre of bed surface from a pile near Beaumenil.

Cultivation of Morelless costata has also been reported on ordinary household garbage mixed with garden earth decomposing in lots near the wood, during one year by H. Sabee (vide Singer, 1961). The use of pulverized rotted pine wood or sawdust of poplar and leaves, twigs, roots and
wood of deciduous trees has also been reported in cultivation experiments (Boyer, 1891; Helm, 1936 & Falck, 1920).

Baker and Matkin (1959) commenting on an unusually abundant growth of morels (Morchella esculenta) the source of inoculum for which was uncertain but which appeared on newly planted raised beds of Cymbidium in a Californian nursery in 1956; note that the growth occurred on slightly charred, ground fir bark which had been fumigated with methyl bromide and suggest this as a possible medium for commercial production of morels. Ramsbottom (1953) states that during and after 1914-18 war the sites of destroyed houses and disused trenches in northern France were in spring veritable gardens of morels, giving the impression that they favour the disturbed ground. He also records an observation where abundant morels appeared in his garden on a site where quantities of paper had been burned, Mitrophora semilibera a species closely related to morels has been grown on earth rich in humus and leaves of Populus tremula (aspen) in France with good results, (vide Singer, 1961).

Singer (1961) reviewing the subject maintains that a method of commercial production is still wanting and suggests continuation of experiments leading to a better understanding of the biology of the genus with subsequent application of these findings for producing commercial crops.

**Taxonomy and distribution**

Morchella has been depicted in the first serious work on and the earliest published illustration of fungi.
"Fungorum Historia" by Clusius Carlous in 1601 (Ramsbottom 1912-13; Krieger, 1922). However, the genus name for the first time appears in "Catalogus Plantarum Sponte Circa Gissam Nascentium" published by J.J. Millenius in 1719. It has appeared in subsequent classical publications on fungi of Micheli (1729), Linnaeus (1753), Cleditsch (1783), Hedwig (1789), Persoon (1801) and Fries (1822) (vide Ramsbottom, 1912-13). The history of the genus, however, may be said to have its official beginning in "Systema Mycologicum" II by F. W. Fries published in 1822, since this is the accepted starting publication for mycological nomenclature on Ascomycetes. Dennis (1968), however, goes to the earlier accepted date 1821 and ascribes the genus to St. Amans published in "Flore Agenaise : 581, 1821".

The genus is placed in the broad group Discomycetes of the class Ascomycetes. This group was first established by Fries in "Summa Vegetabilium Scandinaviae, 1849" with the present significance. Besides Fries other classical workers who have contributed to the classification of the group are P. A. Saccardo of Italy and H. Rehm of Germany (Ramsbottom, 1912-13). It was F. Boudier of France who for the first time in 1879 suggested the presence or absence of the operculum in the ascus as a fundamental basis on which to separate the Discomycetes into two large sections - Operculates and Inoperculates. In his subsequent work "Histoire et classification des Discomycetes d'Europe" published in 1907, he gives a full classification of the group with generic descriptions and list of species. "Icones mycologicae" also published by Boudier in 1905-10 contains
unsurpassed illustrations of Discomycetes and excellent
descriptions of nearly four hundred species, Boudier’s
classification has been followed with or without modifications
by a number of systematists e.g. L.J.Grelet and Marcelle
Le Gal in France, J.A.Nannfeldt in Sweden; F.J.Seaver in
U.S.A. and J.Ramsbottom & C.Rea in England and is the most
accepted one all over the world. Subsequent to Boudier,
Nannfeldt’s (1932) work on Discomycetes is perhaps the most
significant, wherein he proposes a modern system of classifi-
cation of Ascomycetes ( inoperculates ). Nannfeldt’s
classification has been subsequently modified as regards
Pezizales by Madame Le Gal of France ( 1952 ) and has been
adopted by Dennis ( 1968 ).

Morchella and Mitrophora are the two genera included
in the family Morchellaceae of operculate Discomycetes in
Boudier’s classification. Closely related genera like
Ptychoverpa, Verpa and Halvella are placed in another family
Helvellaceae. Seaver ( 1942 ) who follows Boudier’s system
of classification with modifications recognises only two
families of operculate cup fungi - Pezizaceae and Elvelaceae
( = Helvellaceae ). Morchella is included in the family
Elvelaceae along with Durandiomyces, Verpa, Elvela and
Underwoodia. Batra & Batra (1963) in their work on Indian
Discomycetes have recognised three families - Pezizaceae,
Helvellaceae and Sarcoscyphaceae with Morchella included in
Helvellaceae. Dennis ( 1968 ) in his work on British
Ascomycetes adopts the modern method of classification
referred to earlier in which family Morchellaceae is divided
into two tribes - Heterogeneae and Homogeneae. The former includes two genera *Morchella* and *Mitrophora*, while the latter includes *Ptychoverpa*, *Verpa* and *Disciotis*.

Boudier (1897) in his work on morels of France recognised twenty three species in the genus *Morchella* and four species in the closely related genus *Mitrophora*. The two genera were separated on the basis of hymenophore being separated from the stalk only by a shallow furrow (*Morchella*) and hymenophore hanging free in its lower part (*Mitrophora*). Boudier (1907) brought his list of species up to date and enumerated twenty eight in the genus *Morchella*. Costantin (1936) provides a complete key to the species of *Morchella* based on Boudier's work. Parlier Saccardo (1888) recorded twenty four species of *Morchella* in his first work on *Discomycetes* and reported a few more in the subsequent volumes of his monumental work - "*Sylloge fungorum*". He did not recognise the separate genus of *Mitrophora*. Besides the works of Boudier there have been a few other publications dealing with morels (Trelase, 1888; Morgan, 1902; Bataille, 1911; Lagarde, 1923; Overholts, 1934; Groves & Hoare, 1953 and Ghosh & Pathak, 1962). Our knowledge of morels from different parts of the world is derived mainly from the publications on edible mushrooms and in some cases by works on *Discomycetes* group (Bolton, 1788; Cooke, 1875; Krieger, 1936; Seaver, 1942; Ramsbottom & Salfour-Browne, 1951 and Batra & Batra, 1963). Official organs of British and American mycological societies also contain records of morels encountered in these countries on their mycological forays. Interest in collection and description of morels
continue unabated and records of the existing species from new localities and in certain cases new species are being made (Fanhegyi, 1941; Rodriguez & Herrera, 1962; Heim, 1966 and Vladyslaw, 1966).

Winters (1961) records fifteen species for the genus Morchella. Singer (1961) observes that taxonomy of morels is still not definitely worked out. Morgan (1902) was of the opinion that American collection consisted of only two species: Morchella esculenta and M. patula, the other records being synonymous with these two. Lagarde (1923) working on morels of France observed the close relationship between some of Boudier's species. Seaver (1942) in his monograph on North American discomycetes recognises six north American species of the genus. Overholt's (1934) regards Morchella conica only as a form of M. esculenta. Groves & Heare (1953) working on Canadian morels have tried to reduce the known species. Singer (1961) records the new tendency to reduce the recognisable species in the genus. Patra & Patra (1963) merge Morchella conica, M. grassipes and M. deliciosa with M. esculenta. Dennis (1968) recognises only three species in British Isles and maintains that most authors are of the opinion that numerous species described from Europe are variants of two Morchella esculenta and M. elata.

There is little knowledge of the distribution of most fungi. Comprehensive facts and principles regarding geographical distribution will have to wait till many fungi are mapped accurately. Bisby (1943) maintains that
though climate has a controlling effect on the distribution of many fungi, the distribution of hosts and substrata primarily controls distribution of fungi. He also observes that saprophytic fungi have wider distribution than parasitic.

Ainsworth (1961) classifies *Morchella* as a genus especially of temperate regions. Though no proper analysis of the distribution pattern of the genus has been made, most of the records are from the temperate regions. In tropical regions also the species are available at higher altitudes. Heim (1966) has recorded two remarkable tropical species - *Morchella rigidoides* and *M. anteridiformis* from south pacific. The distribution range within United States has been recorded by Seaver (1942). He also refers to a paper by Underwood in which the annual production of morels in the State of Indiana is estimated at 50,000 bushels in 1894. Christensen (1943) maintains that morels are found in abundance in every state of America. The records of forays of British Mycological Society, however, reveal that the genus is not abundant in British Isles. Records from Europe have been many and France probably tops in the frequency of morels in the world. The information on its distribution and frequency from many other regions of the world is scanty.

The record of morels in India dates back to 1831 (vide Cooke, 1870). *Morchella conica*, *M. conica* var.
Acuminate, M. delicosa, M. esculenta, M. gigaspora, M. vulgaris (M. esculenta), M. angustisepa and M. hybrida have been recorded by different workers from India (Butler & Bisby, 1960; Vasudeva, 1962; Chosh & Pathak, 1962 and Sohi et al, 1968). Batra and Batra (1963) after critical study of earlier records maintain that only Morchella esculenta and M. angustisepa exist in the country. They, however, did not have the collection of M. hybrida at their disposal. Instead they mention having examined the material of M. crassipes from India. An analysis of the limited Indian records show that the genus is mainly confined to Northern India. There is only one record (Bhatacharya & Baruah, 1963) from eastern India and has not so far been recorded from southern India (Rangaswami et al, 1970). That it is abundantly found in Kashmir valley is known from early times (vide Cooke, 1870).

Ecology

Ecology of fungi in general has had little attention from mycologists though some studies of ecological nature in macrofungi have been made. Bolton (1788) was the first to relate fungi to vascular plants around them and Ramsbottom (1928) gave the first review on the subject outlining the problems. Gilbert (1928) published a book solely devoted to mycology. Significant contributions in this field were made by T. Shants and Piemeisel (1917); Graham (1927) in U.S.A.; Wilkins and his associates (1937-46) in England; Haas (1933) in Germany; Hofler and his students in Vienna.
(vide Cooke, 1948) and Morten Lange (1948) in Denmark. Studies of limited nature have also been made by Corner (1934), Grainger (1946), Hawker (1954) and Hora (1959) among others. Cooke (1948, '53) has provided us an excellent survey of literature on the subject.

The ephemeral nature and occurrence of the fruit bodies and uncertainty of their appearance, makes the ecological studies of macrofungi difficult. The absence of chlorophyll in fungi leads to either parasitic or saprophytic mode of existence thus making them dependent on phanerogamic vegetation. Wilkins et al. (1937) maintain that distribution of saprophytic fungi is dependent on the nature of their substrate, which in turn is determined by (i) character of the subsoil, (ii) the nature and character of the dominant, subdominant & ground vegetation, and (iii) certain climatic factors such as moisture and temperature. Weir (1918) discussed the effect of altitudinal ranges on the distribution and occurrence of fungi. Graham (1927) was the first to relate the different species to different season of the year and the seasonal distribution of fungi in U.S.A. was also presented by Krieger (1936). Haas (1933) studied the relation of mycoflora with the soil types - sandstone and limestone. Fungi have also been divided according to habitats - grassland, woodland, sanddunes, burnt ground, lignicolous and coprophilous species (Ramsbottom, 1926, 1953; Findlay, 1967). Role of pH in the distribution of fungus species has been dealt by Wilkins et al. (1938), Friedrich (vide
Cooke, 1948) and Grainger (1946). Parallel development of the fungus flora along with succession of higher plants has been established by Graham (1927). Cooke (1948) based on Haas's work provides a classification of species according to their habitats and associations.

It is a matter of common observation that rainfall and temperature have a marked effect on the time of appearance and number of fungus sporophores. Wilkins and Harris (1946) by critical studies established that water content of the substrate and temperature are the major factors influencing sporophore production in both grassland and woodland species. Rhythmic periodicity of the appearance of fungus sporophores is not a function of time but conditions, according to them. They also observed a lag phase in sporophore production, after the onset of what may be regarded as favourable conditions. Hawker (1957) subsequently corroborated these findings and in addition suggested aeration also as an important factor. Earlier Hawker (1954) in her studies on hypogeous fungi found that different species were favoured by different combinations of temperature, rainfall, aeration and pH conditions of the substrate. Grainger (1946) has correlated the autumnal maximum of fungal fructification with the time of the year when soil moisture, soil temperature and the level of available nitrogen are simultaneously sufficient.

Constant association of certain higher fungi with trees was a matter of common knowledge since early times.
However, our knowledge of the existence of a dual relationship of fungi with the roots of green plants begins with the classic work of Frank in 1888 (vide Harley, 1969). He designated these structures formed by the association of fungi with roots of higher plants as mycorrhiza and distinguished two types - ectotrophic and endotrophic. The suggestion that mycorrhizal association is necessary for the fructification of these fungi has been put forward by some. It has also been demonstrated in some species that the fruit bodies assume variable sizes in association with different tree partners (vide Ramsbottom, 1953).

Very little information of ecological nature on Morchella is available in the literature. Morels since early times have been associated with spring season and designated as spring mushrooms. Graham (1927) while studying the seasonal changes of mushroom flora in Chicago region observed that scarcely any member of the genus Morchella is found outside spring. Krieger (1936) while presenting a chart on the seasonal occurrence of fleshy fungi in U.S.A. shows that Morchella is mainly confined to spring months. A number of books published on edible mushrooms in Britain, United States, Canada and other places show that the genus belongs to the spring group (Ramsbottom, 1923; Christensen, 1943; Smith, 1958; Groves, 1962 and Kleijn, 1962).

Information regarding the habitat of Morchella
has also been recorded by a number of workers. They have been noted on charred paper, rubbish, apple pulp from cider factories, sand dunes, deciduous woods, old orchards, burnt places, bombed places and near elm trees (Ramsbottom, 1943, 1953; Singer, 1961). The observation regarding the association of Morchella with burnt places is quite old, as referred earlier. A number of Ascomycetes and a few Basidiomycetes have been associated with burnt places (Ramsbottom, 1953; Krieger, 1936). Moser (1949a) presented a detailed survey and sociologic study on the fungi of burnt area which also abound in Morchella. In a separate study (Moser, 1949b) he described a number of species of Morchella from burnt areas and noted the presence of some abnormal forms which include two new varieties.

Seaver (1909) and Seaver & Clark (1910) investigated the association of Pyronema with burnt situations and came to the conclusion that heating renders insoluble organic matter soluble. Jorgenson and Hodges (1970) in a study on microbial characteristics of burnt forest soil came to the conclusion that burning had no significant effect on the microbial population of the soil. Hora (1969) records the appearance of some typically burnt ground species like Omphalia naura, Coprinus lagopides and Aleuria lilaecina in experimental plots treated with lime. El-Abyad and Webster (1968 a,b) conducted physiological and ecological studies on pyrophilous Discomycetes.

Influence of edaphic factors on the occurrence and distribution of Morchella finds mention in the study
of Grainger (1946) and it has been classified as calcicolous species.

**Physiology**

An understand of the nutrition of fungi is of great significance for various reasons, the most important one being that growth and reproduction of a fungus are completely dependent on its nutrition. Important contributions to our knowledge of the nutritional requirements of fungi have been made all over the world, but our knowledge is by no means complete. Fungi are dependent upon the medium or substrate for all the elements and compounds they require or utilize except molecular oxygen and possibly a little carbon dioxide which are obtained from the atmosphere. From these elements and compounds they synthesize their cellular constituents and obtain the energy necessary for their life processes.

Of all the elements essential for the nutrition of fungi, carbon occupies the foremost position. Fungi require carbon as a main source of energy and as the chief structural element, forming almost half the dry weight of fungus cells. Organic compounds differ in composition, structure and configuration which determines their utilization by fungi. Though fungi may be found that will metabolize almost any carbon containing compound (Perlman, 1965) the common carbon sources in fungal nutrition can be classed into sugars, sugar alcohols, glycosides, sugar acids and organic acids.

Nitrogen is used by fungi for functional as well
as structural purposes, Fungi have been classified into
four main physiological groups according to their nitrogen
Common nitrogen sources are nitrate nitrogen, ammonium
nitrogen and organic nitrogen. Cochrane (1968) maintains
that at present there is not sufficient evidence for
fixation of nitrogen by fungi though some have been reported
to utilize it (vide, Price, 1970).

Hydrogen and Hydroxyl ions are present in all media
and in substrates upon which fungi grow in nature. pH of
the medium exerts a decided effect upon the rate and amount
of growth and many other life processes. Most fungi grow
within the pH range 4-8 though some have a wider range and
a few have been reported to have a narrower range (Hawker,
1950; Lilly & Barnett, 1961 and Tandon, 1961). In contrast
to bacteria, fungi are relatively more able to invade acid
environments.

Temperature affects growth, spore germination,
reproduction and all other activities of the organism. Its
influence on the cellular activities is probably due to
its effect on chemical, physical and physiological processes.
Below 0°c fungal cells may survive but rarely grow and
above 40°c most cells stop growing and soon die (Hawker,
1950). Some fungi are able to grow at unusually high or
abnormally low temperatures. Hawker (1950), Lilly & Barnett
(1961) and Cochrane (1958) have discussed in detail the
influence of physical and chemical factors on the growth and sporulation of fungi.

Physiological studies on the genus *Morchella* have not been given much attention in the past. The few references to work of physiological nature on the genus are those of From (1905), Melin and Miden (1941), Hans Hurni (1946), Brock (1951) and Robbins & Hervey (1959, 1966). From (1905) was the first to report briefly on carbon nutrition, effect of pH and mineral nutrition of *Morchella*. The only available data in considerable detail on the nutrition of *Morchella* refers to *Morchella esculenta* and is presented by Hans Hurni (1946) and Brock (1951), working independently at about the same time they came to almost similar conclusions in regards to the carbon and nitrogen nutrition of *M. esculenta*.

Brock (1951) found that minimum nutritional requirements of *M. esculenta* are relatively simple and it grows quite well at neutral reaction in mineral salt-glucose medium with nitrate as the sole source of nitrogen on agar or in liquid culture. Starch gave the best result among carbon sources followed by maltose, fructose, turanose glucose and sucrose. Polyhydric alcohols and levorotatory methyl sugars supported little growth. Inulin was considered a poor source though From (1905) earlier reported that it was best carbon source.

Brock (1951) further found that the organism can utilize nitrate, ammonium and organic nitrogen.
compounds or compounds which readily yield ammonia such as urea and asparagine are excellent nitrogen sources. Nitrite which is usually toxic for most fungi was found to be a good nitrogen source. Only a few amino acids e.g. cysteine-HCl, aspartic acid, alanine and glutamic acid - HCl were used. Ammonium citrate, thiourea, hydroxylamine - HCl and hydrazine-2 HCl were toxic. The pH-growth curve for the fungus was bimodal with maxima at pH 6.93, which is unusually high for fungi. Hans Hurni (1946) found in addition that *M. esculenta* does not require organic growth factors. Melin and Miden (1941) also observed that thiamin has no effect on the growth of unisporic cultures of *M. conica*.

Robbins & Hervey (1969, 1965) investigating the beneficial effects of the addition of natural preparations especially wood extract on the growth of *M. esculenta* and *M. crassipes* are of the opinion that ash of the natural products is primarily responsible. They further suggest that manganese and calcium portion of the ash may be mainly concerned.

Data on the comparative physiology of different *Morchella* species is completely lacking.

**Submerged culture**

The idea of growing mushrooms for their mycelium rather than their sporophores developed because of or at least was stimulated by the success of submerged culture of *Penicillium* species in the antibiotic field. As
substantial portion of mushrooms are not sold whole, but pulped prior to being added to soups, gravies and sauces; the mushroom mycelium produced by the less expensive method attracted the attention of a number of workers. *Agaricus bisporus* and its progenitor *A. campestris* because of their familiarity and general acceptance were among the first to be tried.

Lambert (1938) was the first to grow successfully *Agaricus campestris* mycelium in submerged culture. Humfeld (1948) however, first suggested a process for the commercial production of *Agaricus campestris* mycelium. Subsequently Humfeld (1950-51) and Humfeld and Sugihara (1949, 1952) tested fifty strains of *Agaricus campestris* and found three particularly well adapted to submerged culture and also developed the process to permit low cost large scale production. Sugihara & Humfeld (1954) reported the submerged culture growth of mycelia of mushroom species belonging to Ascomycetes and Basidiomycetes. Only mycelia of *A. campestris* and *Lepiota rachodes* were found to have pleasant flavour. Eddy (1958) found that out of 20 species of mushrooms only *Morchella esculenta* and *Agaricus campestris* grew well on synthetic media. *Coprinus comatus* the only species to have a strong mushroom like odour, required a medium containing an appreciable quantity of dried autolysed yeast. Submerged culture experiments with a number of other fungi have been reported by various workers (Jennison, 1956; Jennison et al., 1957; Reusser et al., 1958 b; Shukla & Butta, 1965; Chen et al., 1963; Gray, 1965; Yoshida et al., 1965).
Block (1959) has also reviewed the developments in the field.

Though a number of species have been grown successfully in submerged culture in the laboratory, only Agaricus species and Morchella species have been cultivated in large scale pilot plant fermentors and only Morchella species on a commercial scale. Agaricus species did not have the full flavour of fresh mushrooms and only mycelia of Morchella species (morel) are grown today on a commercial scale because of their distinctive flavours (Klis, 1963). Morel mycelium is approved by Food & Drug Administration of U.S.A. as a food supplement (Gilbert, 1960).

Scientists working in United States obtained a number of patents (1950, 1954, 1956, 1958) in the field of submerged mushroom culture and isolated a strain of Morchella, specially adapted to submerged culture. Scientists strain of Morchella has been engineered to commercial scale production (Robinson & Davidson, 1959). Gilbert (1960) presented the first detailed studies on the submerged culture of different Morchella species and found that the mycelium and ascocarp have the same flavour. Intensive work on the submerged culture of morel mushroom mycelium was taken up by Litchfield and his group working at Battelle Memorial Institute, Columbus, Ohio (U.S.A.) and has been reviewed by him (Litchfield, 1964; Litchfield, 1967).

Fungal mycelium has been considered to be a valuable source of protein by a number of workers (Humfeld, 1948; Humfeld & Sugihara, 1949; Robinson & Davidson, 1952; Gilbert & Robinson, 1957; Block, 1960 and Gray, 1966). Humfeld (1948, 1952) and Humfeld and Sugihara (1949) grew mushroom mycelium
of *Agaricus campestris* in submerged culture in synthetic and
in natural substrates such as asparagus-butt juice, pear waste
juice and a rice bran extract; and demonstrated the possibility
of using of a large variety of substrates. Subsequently a
number of other industrial wastes and low cost products were
found as suitable substrates for submerged culture of mushroom
mycelia: citrus press water, molasses, sulfite waste liquor
from the paper and pulp industries, corn steep liquor, cheese
whey, corn canning waste water and pumpkin canning waste,
soyabean whey and cheap high carbohydrate crops (vide,

Sveecos (1954, 1956, 1958) demonstrated that *Morchella*
species particularly *M. esculenta* would grow satisfactorily in
agitated, aerated vessels with simple sugars or waste materials
as substrates. Some carbohydrates and carbohydrate wastes
satisfactory for growing *Morchella* species are glucose, lactose,
maltose, sucrose, xylose, beet molasses, cane molasses,
citrus molasses, corn syrup, corn canning waste, pumpkin
canning waste, sulfite waste liquor and cheese whey (vide,
Litchfield, 1967).

Brock (1951) found that *M. esculenta* gave best growth
on ammonium compounds or compounds which readily yield
ammonia-urea and asparagine, with exception of ammonium
citrate. Neussor, Spencer & Callans (1958 a) reported that
ammonium tartrate was utilized as a nitrogen source by
*Morchella hybrida*. Litchfield & Overbeck (1962) found
ammonium phosphate was a suitable supplement for food
industry waste substrates. Szuecs (1954, 1966) and Litchfield et al. (1963a) have found ammonium salts, urea or corn steep liquor as suitable nitrogen sources. Corn steep liquor supplies unidentified growth factors also. Carbon to nitrogen ratio of the growth medium also affects the protein content of the mycelium (Litchfield et al., 1963a).

Mycelium of different Morchella species will grow over a temperature range of 3 to 36°C (vide Litchfield, 1967) but the highest growth rates were obtained in the temperature range 22 to 28°C (Litchfield, 1964). Aeration rates had a critical effect on yields of mycelium and preferred pH values range from 5.5 to 6.5 (Litchfield et al., 1963a).

The beneficial use of an insoluble inorganic material such as calcium carbonate, dicalcium phosphate, calcium sulphate or an organic material such as cereals as "support material" for pellet formation was demonstrated (Szuecs, 1954). Litchfield et al. (1963) also advocated the use of calcium carbonate as support material. Yields obtained by various Morchella species under different conditions have been presented by Litchfield (1964). Robinson & Davidson (1969) records the yield on large pilot plant run as 24 to 30 g per litre.

Even though a number of genera of mushrooms give good yields in submerged culture system a satisfactory flavour for food use is found in only a few species. A number of workers reported that Morchella species develop sufficient flavour in submerged culture to be promising for food
In general within a given species the strain used is an all important determinant of mycelial flavour and aroma. Flavour may be enhanced by adding either corn steep liquor or preferably dry skim milk to a synthetic medium (Heinemann, 1963). Litchfield (1967b) has presented a detailed study on the flavour development in morel mushroom mycelium.

Economic consideration weigh in producing morel mycelium as a source of protein and it has main advantage as a pleasant flavoured food supplement rather than as a primary protein source (Litchfield, 1967a).

**Nutritional value**

Food is the prime necessity of life. The principal constituents of human and animal diets are: carbohydrates, fats, proteins, vitamins together with water and certain mineral elements. Proteins, fats and carbohydrates are often termed "Proximate principles". The mushrooms are used for dinner table mainly for their culinary properties and only secondarily for their nutritional value. The interest that has been shown in mushrooms as potential sources of food stems from the finding that they are especially rich in most B-group vitamins and in proteins containing many essential amino acids.

Protein deficiency is the world's most serious human nutritional problem (Gray, 1966; Scrimshaw and Behar, 1961). Protein nutrition is so important to young children and applications (Grueca, 1966; Robinson & Davidson, 1969; Gilbert, 1960; Litchfield et al., 1963 and Litchfield, 1967a).
has direct and indirect effect on adult health. Proteins supply the building materials for the body and make good the wear and tear of tissues which is a constant feature of the process of life. The nutritive value of individual proteins depends upon three factors - amount, digestibility and the biological value. The biological value of a protein depends upon the amino acids of which it is composed. There are about 18 amino acids commonly found in dietary proteins. Although all amino acids are essential for tissue formation and various body functions, only some of them - essential amino acids, need to be provided from exogenous supplies. Nutritive value of a protein is mainly dependent on its essential amino acid make up and its digestibility. The ten essential amino acids are: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The interrelationship among certain amino acids are important. Cystine has a sparing action on methionine while tyrosine has a sparing action on phenylalanine.

Not only should a dietary protein contain adequate amounts of essential amino acids but these must also be present as far as possible in balanced proportions. The superiority of animal proteins over proteins of vegetable origin is mainly due to the presence of essential amino acids (especially methionine, tryptophan and lysine) in larger amounts and also in better balanced proportions.

A man weighing 70 kg generally requires about 70 g of
protein per day (Cruickshank, 1961). Of the total protein requirements of seventy grams a day, about thirty grams should be of animal origin (Henahan, 1968).

Amongst mineral salts only four are likely to be deficient in average diets; calcium, phosphorus, iron and iodine and of these four the one usually found most deficient is calcium. A daily allowance of 1.0 g of calcium has been recommended (Aykroyd, 1966).

There have been conflicting claims about the nutritive value of edible mushrooms and mushroom mycelia. Some have assigned exceptionally high nutritional value, while others believe that the nutritional value of mushrooms was next to nil (vide Kuppuswamy et al, 1968). Singer (1961) considers both views as exaggerated and regards them as equivalent to vegetables such as cauliflower. A number of workers have reported on the composition of fruiting bodies of edible mushrooms (Lintzel, 1941; Anderson & Fellers, 1949). The information on the chemical composition of various edible mushrooms has also been compiled by some (Hawker, 1950; Singer, 1961; Aykroyd, 1966). Boletus edulis, Agaricus bisporus, Lentinus edodes, Lactarius deliciosus, Tuber melanospermum, Armillaria mellea, Pleurotus ostreatus and Coprinus comatus are among some edible mushrooms which have been analysed. The only reference to chemical composition of morels refers to Morchella esculenta recorded by Hawker (1950), Cochrane (1958) and Singer (1961). Nutritional value of mushrooms in comparison to other food stuffs has been set forth by
Singer (1961). Proximate analyses of mushroom mycelia has been recorded by a number of workers (Humble, 1948; Humble & Sugihara, 1949; Block et al., 1953) and that of Morchella species by Litchfield et al. (1963b).

Protein content of mushroom sporophores varies from 14 to 43% on dry weight basis, 34-35% being recorded for *Morchella esculenta* (vide Singer, 1961). Protein content of mushroom mycelia including morels on dry weight basis range from 22 to 60% when calculated on a nitrogen x 6.28 basis depending upon the strain and the nitrogen content of the growth medium (Falanghe et al., 1964; Litchfield, 1964a; Litchfield et al., 1963a,b; Falanghe, 1962; Reusser et al., 1968a,b; Block et al., 1953; Humble and Sugihara, 1949). Of the total nitrogen 31 to 37% is non-protein (vide Kuppuswamy et al., 1968). Fitzpatrick (vide, Block et al., 1953) has reported purified mushroom protein having a rather low nitrogen content (11.79%) which needs further investigation to arrive at true estimate of protein. The digestibility of the proteins in different varieties of mushrooms varies from 45.4% to 84.0% (vide Kuppuswamy et al., 1958).

Amino acid analysis of edible mushrooms and fungal mycelia has not been reported much. Litchfield (1967b) presents the list of mushrooms for which amino acid analyses has been reported by various workers. He also presents typical results in a tabular form. Sano et al. (1963); Krzeszkowska et al. (1964, 1965) have also reported
on the amino acid composition of edible mushrooms.

Comparative data on amino acid contents of sporophores and mycelium has been presented only in *Agaricus blazei* (Block et al., 1963). Heinemann & Angels (vide, Singer, 1961) and Heinemann & Casimir (1961) have suggested the relationship between systematics and protein chemistry.

Quantitative analyses of amino acids of morel mushroom mycelium has been presented by Litchfield et al. (1963b) and that of *Tricholoma nudum* by Reussar et al (1963b). Litchfield (1964a) on comparison of the essential amino acid content of the above species with FAO reference pattern concludes that they are deficient in sulfur containing amino acids such as cystine and methionine. Anderson & Jackson (1968) reports similar values for other micro-organisms. Hatanaka (1969) has isolated a new free amino acid from fruit bodies and mycelia of *Morchella* species.

Vitamin content of edible mushrooms has been reported by Fesselen & Fellers (1946); Block et al., (1963); Singer, (1961) and Litchfield (1964b). Litchfield (1964b) has presented the result of assays for B-vitamin content of *Morchella hortensis* and compared it with some earlier records.

Ramage (1930) and Hawker (1950) have reported the results of mineral analysis of ash of fungal fruit bodies.

Very little information is available on biological
value of mushroom protein. Lintzel (1941, 1943) fed
fruiting bodies of mushrooms - *Morchella esculenta*,
*Agaricus campestris* and *Cantharellus cibarius* to men at
100% of dietary protein level and reported that these
mushrooms were equivalent to muscle protein in nutritional
value. He also reported that when used as the only source
of dietary protein 100 - 200 g dry weight of mushrooms
per day was required to maintain nutritional balance in
a normal subject weighing 70 kg. Litchfield (1968) is of
the view that confirmatory evidence is lacking. Gilbert
(1960) records the lack of toxicity of morel mushroom
mycelium.