Chapter 24
Functional Activities of Ferns for Human Health

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24.1 Introduction

Most people think that there are limited uses for ferns. However, these plants have given many health benefits to humans since ancient times. Not surprisingly, herbal medicines of Chinese, Indian, and Native American peoples include ferns. These cultures have used them for food, tea, and drugs. In the present day, the functional activities of ferns and fern allies for human health have been studied using several advanced scientific technologies. Compared to flowering plants, ferns and fern allies have limited use to human health in modern times. So, various functional activities for human life and possibilities of industrial application of ferns and fern allies will be discussed in this chapter.

Plants normally produce various secondary metabolites not only to adapt to their environment but also to defend themselves against biotic or abiotic stress, such as high light intensity, extremely high or low temperature, high salinity, drought and natural enemies. To provide protection against adverse effects of their environment, plants have the tendency to produce many kinds of secondary metabolites in severe conditions (Bennett and Wallsgrove 2006). These metabolites are polyphenols, flavonoids, terpenoids, steroids, quinones, alkaloids, polysaccharides and so on (Swain 1977). These metabolites are also engaged with the color, flavor and aroma of plants. These functional metabolites have properties which prevent and cure various diseases as well as aging in mammals including humans.

Since ferns and fern allies have survived from Paleozoic times, they have adapted with many more various changes of environment than the other primitive vascular plants (Wallace et al. 1991). Therefore, ferns are expected to have many useful secondary metabolites than other plants. Ferns were reported to have many useful phytochemicals (secondary metabolites) such as flavonoids, steroids, alkaloids, phenols, triterpenoid compounds, varieties of amino acids and fatty acids (Zeng-fu et al. 2008).

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H. Fernández et al. (eds.), *Working with Ferns: Issues and Applications*,
DOI 10.1007/978-1-4419-7162-3_24,

They also have some unique secondary metabolites which have not been discovered in higher plants (Zhao et al. 2007; Shinozaki et al. 2008).

Ferns have various types of useful phytochemicals. Polyphenols are useful phytochemicals which provide health benefits such as antioxidants. Antioxidant is generally recognized to reduce the risk factors of chronic disease. From experiments for screening of total polyphenol contents of 37 ferns and fern allies, *Polystichum lepidocaulon* and *Polystichum polyblepharum* were reported to have more than 13% of total polyphenols from dried materials of both fronds and rhizomes (Shin and Lee 2010; Shin 2010). In addition, fronds of *Davallia mariesii* and rhizomes of *Cyrtomium fortune*, *Dicranopteris pedata*, *Athyrium niponicum* and *Dryopteris nipponensis* showed more than 10% of total polyphenols from dried materials.

Due to an increased concern about human health, longevity and eco-friendly life style, the health supplement markets are expanding rapidly. Synthetic compounds were popular due to their cheap price and quick efficacy in the past. However many studies reported their side effects, such as carcinogenesis (Branen 1975). The preference of natural substances has increased rapidly worldwide (Nakatani 1992). In these circumstances, human interests for ferns and fern allies will be not only ornamental but also medicinal plants.

Ferns have lived with human beings for a long time. They influenced millions of human lives as traditional medicinal cures or treatments for ascarid disease, cold, diarrhea, burn, trauma bleeding, and more in many countries (May 1978; Wu 1990; Benjamin and Manickam 2007). Recently, high bioactivities of traditional medicinal ferns were analyzed (Table 24.1). They were reported to have various bioactivities, such as a antioxidant (Carcia et al. 2006; Chen et al. 2007; Ding et al. 2008; Shin and Lee 2010), antimicrobial (Maruzzella 1961; Banerjee and Sen 1980, Parihar and Bohra 2002; Singh et al. 2008a, b), antiviral (McCutcheon et al. 1995), anti-inflammatory (Liu et al. 1998; Punzon et al. 2003), antitumor (Konoshima et al. 1996) and anti-HIV (Mizushina et al. 1998) and so on. Out of all these, the most useful bioactivity for human life is antioxidant activity.

24.2 Natural Antioxidant

The most important function of antioxidants is reducing reactive oxygen species (ROS). ROS are a byproduct of respiration. They can be beneficial to the human body by removing pathogens and old proteins. However, an overproduction of ROS can cause various factors such as environmental pollutions, stresses, synthetic substances, etc. They could eventually be responsible for chronic diseases including aging, cancer, cardiovascular diseases, rheumatoid arthritis, atherosclerosis, etc. (Finkel and Holbrook 2000; Yildirim et al. 2000; Gulcin et al. 2002; Mau et al. 2002).

Plants have antioxidant systems for self-protection against biotic and abiotic stress conditions (Hossain et al. 2007). These antioxidant activities of plants have useful effects on human bodies. Ferns and fern allies exposed to several stresses are thought to be effective antioxidant agents for protecting against aging and chronic disease. Recently, efficient antioxidant properties of ferns were reported.

Table 24.1 Representative ferns expressed useful functional activities

Bioactivities	Ferns	Reference
Antioxidant	*Braomea insignis*	Ding et al. (2008)
	Nothoperanema hendersonii	Ding et al. (2008)
	Polypodium leucotomos	Carcia et al. (2006), Gombau et al. (2006)
	Polystichum semifertile	Ding et al. (2008)
	Pteris ensiformis	Chen et al. (2007)
Antimicrobial	*Adiantum capillus-veneris*	Guha et al. (2004)
	A. caudatum, A. peruvianum	Singh et al. (2008a)
	A. venustum	
	A. incisum	Lakchmi and Pullaiah (2006)
	A. latifolium	Lakshmi et al. (2006)
	Dryopteris crassirizoma	Lee et al. (2009)
	Pteris biaurita	Dalli et al. (2007)
	P. multifida	Hum et al. (2008)
	P. vittata	Singh et al. (2008b)
Antiviral	*P. glycyrrhiza*	McCutcheon et al. (1993, 1995)
	P. vulgare, P. aureum	Husson et al. (1986)
Anti-inflammatory	*Blechnum occidentale*	Nonato et al. (2009)
	Dryopteris sp.	Otsuka et al. (1972)
	Phlebodium decumanum	Punzon et al. (2003)
	Polypodium sp.	Liu et al. (1998)
	P. ensiformis	Wu et al. (2005)
Antitumor	Triterpenoids hydrocarbons isolated from *Polypodium nipponica, P. formosanum, P. vulgare, P. fauriei, P. virginianum, Dryopteris crassirizoma, Adiantum monochlamys,* and *Oleandra wallichii*	Konoshima et al. (1996)
Anti-HIV	*Athyrium niponicum*	Mizushina et al. (1998)

Antioxidant activities (DPPH radical and ABTS radical cation scavenging) of frond and rhizome extracts of several genus such as *Davallia*, *Hypolepis*, *Pteridium*, *Cytominum*, *Dryopteris*, *Polystichum*, *Dicranopteris*, *Lycopodium*, *Osmunda*, *Adiatum*, *Coniogramme*, *Polypodium*, *Pyrrosia*, *Pteris*, *Lygodium*, *Selaginella*, *Thelypteris*, *Athyrium*, *Matteuccia*, *Onoclea* and *Woodsia* were analyzed (Shin 2010). As a result, several ferns showed vigorous antioxidant activities on scavenging of DPPH and ABTS radicals. Specially, Dryopteridaceae, Osmundaceae, Woodsiaceae exhibit powerful antioxidant activities. And some crude extracts obtained from ferns showed powerful antioxidant activities more than vitamin C or BHT (synthetic antioxidant) (Table 24.2). So, we think that most ferns have huge potential abilities as antioxidants. Thus, we expect that analyzing antioxidant activities in many ferns will result in the development of health-care products for aging and chronic disease by their high bioactivities.

Table 24.2 Fern's methanol extracts showed higher antioxidant activities than ascorbic acid or BHT (Shin 2010)

Family	Scientific name	Parts	DPPH radical scavenging	
			RC_{50} (mg/mL)[a]	ABTS radical scavenging
	Ascorbic acid[b]		0.03	0.20
	BHT[c]		0.12	0.22
Davalliaceae	*Davallia mariesii*	Frond	0.05	0.06
		Rhizome	0.08	0.07
Dryopteridaceae	*Cyrtomium fortunei*	Rhizome	0.03	0.11
	Dryopteris crassirhizoma	Rhizome	0.11	0.11
	D. nipponensis	Frond	0.11	0.14
		Rhizome	0.05	0.06
	Polystichum lepidocaulon	Frond	0.05	0.09
		Rhizome	0.04	0.04
	P. polyblepharum	Frond	0.08	0.10
		Rhizome	0.02	0.03
Gleicheniaceae	*Dicranopteris pedata*	Rhizome	0.03	0.03
Osmundaceae	*Osmunda cinnamomea var. fokiensis*	Rhizome	0.06	0.08
	O. japonica	Rhizome	0.08	0.10
Parkeriaceae	*Adiantum pedatum*	Rhizome	0.06	0.07
Polypodicaceae	*Pyrrosia lingua*	Frond	0.11	0.08
Schizaeaceae	*Lygodium japonicum*	Rhizome	0.07	0.09
Thelypteridaceae	*Thelypteris acuminata*	Rhizome	0.06	0.06
Woodsiaceae	*A. niponicum*	Rhizome	0.04	0.07
	Matteuccia struthiopteris	Rhizome	0.11	0.14
	Onoclea sensibilis var. *interrupta*	Rhizome	0.11	0.15

[a]Concentration of the soluble solids which is required to DPPH and ABTS radical scavenging 50%
[b]Positive control as a natural antioxidant
[c]Positive control as a synthetic antioxidant

24.3 Foods

In Europe and America, a few ferns, such as ostrich fern, were used for food. However, in Oceania and Asia, there are so many ferns used as foods as main or side dishes and traded in market place (Table 24.3). Especially in Korea, the dried and steamed fiddle head of brackens are important as ancestral service food for Thanksgiving Day, New Year's Day, and home ceremony for ancestors every year.

It is possible to preserve the fiddle heads of ferns as food materials. The preservation methods for fiddleheads are extremely simple. Clean fiddleheads should be steam boiled in hot water with or without ash. Boiled ferns would be dried under sunny conditions or preserved in a salt layer. Then they could be preserved for 2–3 years. When they are needed, dried fiddleheads are boiled and washed with running water again. After draining the water, it would be cooked with mashed garlic, salt, sesame oil, and soybean sources. Salted fiddleheads should be washed again with running water and cooked like dried matter. In USA, boiled fiddleheads are commonly prepared with butter, cider or wine vinegar and a bit of pepper. In Northern New England, some people make pickles with fiddleheads. The cooked fiddleheads have a soft and rich taste; sometimes they taste a bit like asparagus but are much tougher.

Bracken fiddleheads are considered as a nutritionally rich food in Korea. They contain significant amounts of protein, fiber, vitamins, and minerals. However in many countries, brackens are known as poisoning plants because of their carcinogenic and antithiamin properties. The carcinogenic substance of bracken is ptaquiloside

Table 24.3 Edible ferns often used worldwide (Copeland 1942; Thakur et al. 1998; Shin 2010; Wei 2010)

Scientific name	English name	Countries	Edible parts
Athyrium acutipinnulum		Korea	Fiddlehead
A. brevifrons		Korea	Fiddlehead
A. distentifolium	Alpine Lady-Fern	Korea	Fiddlehead
A. esculentum	Vegetable fern, Pako fern	Asia, Oceania	Fiddlehead
Diplazium squamigerum		Japan	Fiddlehead
Matteuccia struthiopteris	Ostric fern	Canada, China, Europe, Malaysia, India, Japan, USA	Fiddlehead
Osmunda cinnamomea	Cinnamon fern	East Asis	Fiddlehead
O. japonica	Flowering fern	East Asia	Fiddlehead
O. regalis	Royal fern	Worldwide	Fiddlehead
Pteridium aquilinum var. *latiusculum*	Bracken	Worldwide	Fiddlehead
Stenochlaena palustris	High climbing fern	South Pacific, India.	Fiddlehead
Ceratopteris	Swamp fern, water lettuce, water sprite	Asia, Australia	Leaves
Cyathea	Tree fern	Oceania	Young leaves, terminal bud

(Hirono et al. 1984). Ptaquiloside is very carcinogenic in mammals, especially ruminants, which repetitively ingest huge amounts of bracken. However, bracken consumption does not lead to carcinogenesis in humans because people eat bracken in smaller quantities than animals, and do not eat the bracken repetitively. Several other foods also contain carcinogenic substances. Estragole is contained in basil, fennel and tarragon (Miller et al. 1983; Bender and Eisenbarth 2007), safrole in cinnamon, camphor, nutmeg, ginger, cocoa and pepper (Ioannides et al. 1981; Bender and Eisenbarth 2007), pyrrolizidine alkaloids in coltsfoot, comfrey and Indian plantain (Bender and Eisenbarth 2007), and agaritine in meadow mushroom (Bender and Eisenbarth 2007). Also, several vegetables, such as beets, celery, radishes, lettuce, spinach, etc., have nitrate (Wolff and Wasserman 1972). Nitrate is not a carcinogenic substance, but nitrosamine derived from nitrate is a strong carcinogenic in the human body (Du et al. 2007). Nevertheless, these products are regularly used as delicious and healthy foods. When people eat 350 g fiddlehead of bracken every day, it can cause cancer (Ham 2004). However, people could not get cancer by consuming bracken because nobody can eat more than 350 g of fiddlehead every day.

The antithiamin activity of bracken is extinguished during washing in running water after boiling with or without ashes or sodium hydrogen carbonate. Furthermore, the antithiamin substances in brackens, such as astragalin, isoquercitrin, rutin, caffeic acid, tannic acid, etc., are known as useful natural substances for anticancer or antioxidant in the present time (Kweon 1986; Cai et al. 2004; Katsube et al. 2006). So, the fiddlehead of bracken can be used as a tasty side dish helpful to human health.

While toxicities caused by carcinogenesis and antithiamin activities of bracken fern have been highlighted, the pharmacological effects of the fiddleheads or whole plants of ferns and fern allies are underestimated. However, several healthy effects of ferns and fern allies are currently well known. For example, the glycoprotein isolated from bracken fiddlehead has immune function (Park et al. 1998), and the acidic polysaccharides isolated from the hot water extract of dried bracken fiddlehead has anti-complementary activity (Oh et al. 1994). Also, the fiddlehead of *Athyrium acutipinulum* has strong antioxidant effects (Lee et al. 2005). So, we expect that more people will enjoy the taste and useful function of young fiddlehead of ferns in the future.

24.4 Natural Antimicrobial Agents

As global temperatures are rising steadily, the duration of the summer season is also increasing in many countries currently. Therefore, the optimal conditions for living of pathogenic bacteria is also increasing. Bacteria including *Listeria*, *Escherichia coli*, *Salmonella*, *Vibrio*, *Staphyococcus*, etc. are vigorously propagated in 37–40°C (Madigan et al. 1997). So, various side effects, such as food poisoning, infection, spoiled food, and more, are expected with the increase of harmful microbial activities. According to WHO, increasing resistance to antibiotics is a growing problem in many countries even in developed countries. Thus, antimicrobial substances are being developed very rapidly. Especially, interest in natural antioxidant agents is rapidly increasing due to the side effects of synthetic substances.

The extracts obtained from ferns and fern allies have effective antimicrobial activities against gram positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*), gram negative bacteria (*E. coli*, *Salmonella typhi*, *Pseudomonas aeruginosa*), as well as fungi (Banerjee and Sen 1980; Vincent and Kanna 2007; Lee et al. 2009). Especially, the genus *Dryopteris* showed vigorous antibiotic activities. *D. crassirhizoma* and *D. filix-mas* can be used against MRSA (Methicillin resistant *S. aureus*) (Lee et al. 2009), and *D. cochleata* against gram positive and negative bacteria and fungi (Banerjee and Sen 1980). Also *D. crassirhizoma* is patented as an anti-tooth decay substance (Park et al. 1995) because of its high activity against *Streptococcus* in Korea.

However, frond of *A. niponicum* and *Hypolepis punctata* are more efficient than *D. crassirhizoma* against *Streptococcus* such as *S. mutans* and *S. sobrinus* (Shin 2010). Several ferns and fern allies were also reported to have excellent antimicrobial activities in *S. mutans* and *S. sobrinus* similar to *D. crassirhizoma* (Table 24.4). Therefore, ferns and fern allies can be used as efficient natural antimicrobial ingredients against several harmful microbials. They could be developed into antibiotic sprays, packing material, toothpaste, hand wash, etc. for protecting the human body and our living environment from undesirable microbials. Most Pteridophytes are known to contain antimicrobial substances such as polyphenols and flavonoids (Francisco and Cooper-Driver 1984). It is possible that several non-analyzed ferns and fern allies could contain effective antibiotic substances. So, the more antibiotic activities of the Pteridophytes are analyzed, the more natural antibiotics could be developed.

Table 24.4 Ferns expressed higher anti-tooth decay activities in the same concentration of methanol extract than rhizome of *Dryopteris crassirhizoma* (Shin 2010)

		Clear zone (mm)	
Scientific name	Parts	*Streptococcus mutans*	*S. sobrinus*
Dryopteris crassirhizoma	Rhizome	16 ± 1.5	14 ± 0.7
A. niponicum	Rhizome	16 ± 1.0	15 ± 0.3
Dicranopteris pedata	Rhizome	15 ± 0.3	15 ± 0.3
Dryopteris fragrans var. *remotiuscula*	Frond	17 ± 0.6	14 ± 0.6
Lygodium japonicum	Rhizome	16 ± 0.3	15 ± 0.3
Osmunda japonica	Rhizome	17 ± 0.3	16 ± 0.7
Onoclea sensibilis var. *interrupta*	Rhizome	15 ± 0.9	16 ± 0.6
Polystichum lepidocaulon	Frond	18 ± 0.6	16 ± 0.7
Polystichum lepidocaulon	Rhizome	18 ± 0.0	18 ± 0.0
Pteris cretica	Rhizome	16 ± 1.2	15 ± 0.3
Thelypteris acuminata	Rhizome	16 ± 0.9	15 ± 0.6

24.5 Cosmetic Ingredient

Ferns can be used in cosmetic materials. For example, some *Dryopteris* spp. exhibit strong antimicrobial activities against *Propionibacterium acnes*, known as a main factor of acne (pimple) (Kim et al. 2006). Therefore, the extracts obtained from some ferns could be utilized as effective natural cosmetic ingredients for the treatment or prevention of acne. Furthermore, many ferns and fern allies normally contain more phenolic compounds than other plants. The phenolic compounds of plants are known to have beneficial skin care effects such as the prevention of UV-induced skin damage (Svobodová et al. 2003; Tanaka et al. 2004), anti-wrinkle (An et al. 2005), skin-whitening (Parvez et al. 2006), etc. Many plant extracts, which contain high phenolic compounds, are currently used as ingredients of natural body and facial cosmetics such as cleanser, toner, moisturizer, shampoo, conditioner, and so on.

Several ferns contain phytoecdysteroids which do not exist in most plants. The phytoecdysteroids, such as ecdysone, show the effects of cell regeneration, skin texture refinement and skin barrier strengthening (Lin and Lin 1989; Meybeck et al. 1997). So, it is used as a cosmetic ingredient. Since fern spores are not villains in hay fever (Moran 2004), the cosmetics including fern spores are patented in Korea. Such a cosmetic is a facial scrub product including spores of bracken (Jin et al. 2005). Due to the very small particle size of bracken spores, the scrub including spores does not cause the skin abrasion. Therefore scrubbing the face or body with spores could promote blood circulation and remove dead skin cells smoothly. Other patented uses include face mask, powder foundation and compact powder containing the ground or skimmed spores of *Lygodium japonicum* (Son et al. 1999). The face mask containing spores of *L. japonicum* could increase the effects of skin refinement and cleansing. The powder foundation or compact powder containing spores of *L. japonicum* could also increase color expression and control discoloration due to the absorption of sweat and sebum. So, various parts of ferns could be effectively used as natural cosmetic ingredients for skin healing, skin smoothening, anti-acne and protection from aging or UV damage. However, as there are fewer natural cosmetics with ferns as main ingredients than with flowering plants, more research of ferns for application to cosmetic material is required.

24.6 Air Purifier

Ferns are useful not only as ornamental plants but also as air cleaning plants. As ornamental plants, ferns have great value including their beautiful leaves and rhizomes. According to research by NASA and KRDA (Korea Rural Development Administration), many fern species also show strong air purification activities of volatile formaldehyde removal. For example, *Nephrolepis exaltata* (Boston fern) and *Nephrolepis obliterata* (Kimberly queen fern) are included in NASA's 50 air purifying plants for homes and offices, with their ranks as 9th and 13th, respectively. According to

Table 24.5 Ferns showed higher formaldehyde removal effect than *Dypsis lutescens* (KRDA 2006)

Scientific name	Amount of formaldehyde removal ($\mu g/m^3/cm^2$ plant volume)
Dypsis lutescens	0.81
Cyrtomium caryotideum var. *coreanum* Nakai	1.09
Davallia mariesii Moore ex Bak.	3.56
Microlepia strigosa (Thunb.) C. Presl	1.03
Osmunda japonica Thunb.	6.37
Polypodium formosanum Bak.	3.03
Pteris multifida Poir.	1.76
P. dispar Kunze	1.44
Sceptridium ternatum (Thunb.) Sw.	1.00
Selaginella tamariscina (P. Beauv.) Spring	4.24

NASA's report, *N. exaltata* and *N. obliterata* have benefits for reducing indoor air pollution such as formaldehyde, xylene and toluene. Furthermore, *N. exaltata* is reported as the most efficient species for removing formaldehyde.

Formaldehyde is the most common indoor volatile organic compound (VOC) with substantially high concentrations. Formaldehyde has several side effects to human beings such as nausea, sore throat, watery eyes, eye burning sensations, headaches, fatigue, and so on (Olsen and Dossing 1982; US CPSC 1997). Therefore, the formaldehyde-absorbing ability is one of the most effective functions of ornamental plants. Also according to KRDA, several ferns and fern allies show high efficiency of formaldehyde removal indoors (Table 24.5). They tested the formaldehyde removal effects of 84 species of plants. *Osmunda japonica* (similar to royal fern) showed the best formaldehyde removal in chamber. In addition, *Selaginella tamariscina*, *Davallia mariesii*, *Polypodium formosanum* and *Pteris multifida* have been ranked as highly efficient formaldehyde-removing plants. Other ferns, such as *Pteris dispar*, *Cyrtomium caryotideum* var. *koreanum*, and *Sceptrium ternatum*, showed better formaldehyde removal than areca palm tree (the best air purifying plant ranked by NASA). So, ferns could purify the air just by keeping them indoors or outdoors. Also we expect that many ferns in addition to the above-mentioned may have efficient formaldehyde removal activities. They also could remove many other volatile organic compounds (VOCs). So, more studies about the air purifying ability of ferns are necessary. Since ferns grow well in shady places, they can be adapted to indoor, even bedroom, restroom and bathroom use. Moreover, ferns are high quality ornamental plants.

24.7 The Future of Ferns and Fern Allies

Many people have been fascinated with ferns and fern allies for their beauty and medicinal properties for a long time. But in the present days, their value has been underestimated than in the past since people have discovered many other useful plants. Even though their useful functions for human have not yet been analyzed thoroughly, ferns and fern allies have many efficient functional activities for human life. The leaves (fronds), spores, fiddle heads, rhizomes, and roots of ferns and fern allies have infinite potential for improving the quality of human life because of their biological activities. They can be applicable to commercial products such as food, medicine, cosmetics, ornamental materials, household products, and more. Negative effects of ferns, such as carcinogenesis, are more magnified than positive effects. In spite of their toxicity, many ferns and fern allies are more beneficial.

Ferns and fern allies also have other advantages for their propagation and culture. Due to adaptation to various environmental conditions for a long time, they are easier to propagate and cultivate than other plants in general (Lee 2004). They can be propagated rapidly using tissue culture techniques. For example, gametophytes are mass-propagated in vitro, and then the juvenile sporophytes are induced from in vitro cultured gametophytes in pots. Also, many ferns and fern allies grow rapidly and produce huge biomass in short periods. So, they can be used as cost-effective ingredients applied to the manufacturing of various functional goods and healthy products for human beings.

The use of ferns for personal health care and environmental esthetics is ecologically sound. Ferns are integral plants which provide food and medicine for all inhabitants. They are in every forest, jungle, rock, mountain and garden. They have a great biodiversity and are representatives of plant evolution level. Now they include wild and cultivated plants. We hope that many people join in studying the various bioactivities of ferns and fern allies for human life. As a result, more people could enjoy a healthy and eco-friendly life with ferns and fern allies.

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