In the competitive world of sports, the smallest advantage can make an enormous difference in the outcome of a contest. A substance that improves an athlete's strength, speed, or endurance is called an ergogenic aid.

The most effective ergogenic aids are both dangerous and illegal: stimulants, anabolic steroids, and human growth hormone. Numerous natural options are marketed as alternatives. In this article, we explore the many supplements used in the hopes of improving sports performance.

For additional sports-related articles, see Sports and Fitness Support: Enhancing Recovery and Sports Injuries.

Principal Proposed Natural Treatments

Two natural supplements have shown meaningful promise as ergogenic aids: creatine and HMB.

Creatine

Creatine, one of the best-selling and best-documented supplements for enhancing athletic performance, is a naturally occurring substance that plays an important role in the production of energy in the body. The body converts creatine to phosphocreatine, a form of stored energy used by muscles. In theory, taking supplemental creatine will build up a reserve of phosphocreatine in the muscles to help them perform on demand. Supplemental creatine may also help the body make new phosphocreatine faster when it has been used up by intense activity.

However, the balance of current evidence suggests that that if creatine supplements have any benefit for sports
performance, it is slight and limited to highly specific forms of exercise.

Several small double-blind studies have found that creatine can improve performance in exercises that involve repeated short bursts of high-intensity activity with intervening rest periods of adequate length.

For example, a double-blind, placebo-controlled study investigated creatine and swimming performance in 18 men and 14 women.¹ Men taking the supplement had significant increases in speed when doing six bouts of 50-meter swims started at 3-minute intervals, compared to men taking placebo. However, their speed did not improve when swimming 10 sets of 25-yard lengths started at 1-minute intervals. Researchers theorize that the shorter rest time between laps was not enough for the swimmers' bodies to resynthesize phosphocreatine.

Interestingly, none of the women enrolled in the study showed any improvement with the creatine supplement. The authors of this study noted that women normally have more creatine in their muscle tissue than men do, so perhaps creatine supplementation (at least at this level) is not of benefit to women, as it appears to be for men. Further research is needed to fully understand the difference between the genders in response to creatine.

In an earlier double-blind study, 16 physical education students carried out ten 6-second bursts of extremely intense exercise on a stationary bicycle, separated by 30 seconds of rest.² The results showed that the students who took 20 g of creatine for 6 days were better able to maintain cycle speed throughout the repetitions. Many other studies showed similar improvements in performance capacity involving repeated bursts of action.²⁻⁴ However, there have been negative results as well; in general, minimal to no benefits have been seen in studies involving athletes engaged in normal sports rather than contrived laboratory tests.²⁻⁷,¹⁴³⁻¹⁴⁶

In contrast, studies of endurance or nonrepetitive aerobic burst exercise generally have not shown benefits from creatine supplementation.⁶⁻⁸,¹¹⁺¹⁴⁷⁻¹⁴⁸ Therefore, creatine probably won't help you with marathon running or single sprints.

Besides repetitive burst exercise, creatine has also shown promise for increasing isometric exercise capacity (pushing against a fixed resistance), in some, but not all studies.⁴⁻¹³,¹⁴⁹⁻¹⁵¹ In addition, two double-blind, placebo-controlled studies, each lasting 28 days, provide some evidence that creatine as well as creatine plus hydroxymethyl butyrate (HMB) (see below) can increase lean muscle and bone mass.¹⁴ However, one double-blind trial failed to find creatine helpful for enhancing general fitness, including resistance exercise performance, in male seniors.¹²⁵

The contradictory results seen in these small trials suggest that creatine offers at most a very modest sports performance benefit. For more information, including dosage and safety issues, see the full Creatine article.

Hydroxymethyl Butyrate

Technically beta-hydroxy beta-methylbutyric acid, HMB is a chemical that occurs naturally in the body when the amino acid leucine breaks down. Leucine is found in particularly high concentrations in muscles. During athletic training, damage to the muscles leads to the breakdown of leucine as well as increased HMB levels. Some evidence suggests that taking HMB supplements might signal the body to slow down the destruction of muscle tissue.¹⁵ On this basis, HMB has been studied as a sports performance supplement for enhancing strength and muscle mass.

According to many (but not all) of the small double-blind trials that have been reported, HMB appears to improve muscle-growth response to weight training.¹⁴⁻²⁰ For example, in a controlled study, 41 male volunteers aged 19 to 29 were given either 0, 1.5, or 3 g of HMB daily for 3 weeks.¹⁷ The participants also lifted weights 3 days a week according to a defined (rather severe) schedule. The results suggested that HMB can enhance strength and muscle mass in direct proportion to intake.

In another controlled study reported in the same article, 32 male volunteers took either 3 g of HMB or placebo daily, and then lifted weights for 2 or 3 hours daily, 6 days a week for 7 weeks. The HMB group saw a significantly greater increase in bench-press strength than the placebo group. However, there was no significant difference in body weight or fat mass by the end of the study.
Similarly, a double-blind, placebo-controlled trial of 39 men and 36 women found that over 4 weeks, HMB supplementation improved response to weight training.19

Two placebo-controlled studies of women found that 3 g of HMB had no effect on lean body mass and strength in sedentary women, but it did provide an additional benefit when combined with weight training.18 In addition, a double-blind study of 31 men and women, all 70 years old and undergoing resistance training, found significant improvements in fat-free mass attributable to the use of HMB (3 g daily).21

However, there have been negative studies as well.14,20,22

All of these studies were small and therefore, their results are ultimately not terribly reliable. Larger studies will be necessary to truly establish whether HMB is helpful for power athletes working to enhance strength and muscle mass.

For more information, including dosage and safety issues, see the full HMB article.

Other Proposed Natural Treatments

Numerous other supplements are marketed as ergogenic aids, said to improve speed, strength, or endurance. Unfortunately, the evidence that they work is marginal at best, and in many cases the best available evidence indicates that these substances are not effective.

Ginseng

There are three different herbs commonly called ginseng: Asian or Korean ginseng (Panax ginseng), American ginseng (Panax quinquefolius), and Siberian "ginseng" (Eleutherococcus senticosus). The latter is actually not ginseng at all, but the Russian scientists responsible for promoting it believe that it functions identically. According to some experts, a fourth herb, ciwujia, is actually Eleutherococcus, while others claim it is a related but different species.

Panax ginseng has shown some promise as a mild ergogenic aid, but published evidence remains at best incomplete and contradictory. Other forms of ginseng generally lack any meaningful supporting evidence.

For example, an 8-week, double-blind, placebo-controlled trial evaluated the effects of Panax ginseng with and without exercise in 41 people.24 The participants were given either ginseng or placebo, and then underwent exercise training or remained untrained throughout the study. The results showed that ginseng improved aerobic capacity in people who did not exercise, but offered no benefit in those who did exercise.

In a 9-week, double-blind, placebo-controlled trial of 30 highly trained athletes, treatment with Panax ginseng or Panax ginseng plus vitamin E produced significant improvements in aerobic capacity.25 Another double-blind, placebo-controlled trial of 37 participants also found some benefit.26 Also, a double-blind, placebo-controlled study of 120 people found that ginseng gradually improved reaction time and lung function over a 12-week treatment period among participants from 40 to 60 years old.27 (No benefits were seen in younger people.)

On the other hand, in an 8-week, double-blind trial that followed 60 healthy men in their 20s, no benefit with Panax ginseng could be demonstrated.179 Many other small trials of Panax ginseng have failed to find evidence of benefit.28-36,126

These mixed outcomes suggest that Panax ginseng is only slightly effective at best.

A double-blind study of 20 endurance athletes over an 8-week period failed to find evidence of benefit with a standard eleutherococcus formulation.32 Lack of benefit was also seen in another small double-blind crossover trial.38 Furthermore, in a small double-blind, placebo-controlled trial of endurance athletes, use of
eleutherococcus actually increased physiologic signs of stress during intensive training.\textsuperscript{36} Ciwujia has not yet been studied in meaningful double-blind trials.

For more information, including dosage and safety issues, see the full \textit{Ginseng} and \textit{Eleutherococcus} articles.

**Medium-chain Triglycerides**

Medium-chain triglycerides (MCTs) are fats with an unusual chemical structure that allows the body to digest them easily. Most fats are broken down in the intestine and reassembled into a special form that can be transported in the blood. But MCTs are absorbed intact and taken to the liver, where they are used directly for energy. In this sense, they are processed very similarly to carbohydrates. For that reason, MCTs have been proposed as an alternative to "carbo-loading" (consumption of a large quantity of carbohydrates prior to intense physical exercise) for providing a concentrated source of easily utilized energy.

A number of double-blind studies have evaluated MCTs’ effects on high-intensity or endurance exercise performance, but the results have been thoroughly inconsistent.\textsuperscript{39-44} This is not surprising because all of the studies were too small to properly eliminate the effects of chance.

For more information, including dosage and safety issues, see the full \textit{MCTs} article.

**Iron**

The majority of athletes are probably not iron-deficient, and you shouldn't take iron supplements if you already have enough iron in your body. However, if you are deficient in this essential mineral, iron supplements may enhance athletic training.

A double-blind, placebo-controlled trial of 42 nonanemic women with evidence of slightly low iron reserves found that iron supplements significantly increased the benefits gained from exercise.\textsuperscript{35} Participants were put on a daily aerobic training program for the latter 4 weeks of this 6-week trial. At the end of the trial, those receiving iron showed significantly greater gains in speed and endurance than those given placebo.

In addition, a double-blind, placebo-controlled study of 40 nonanemic elite athletes with mildly low iron stores found that 12 weeks of iron supplementation enhanced aerobic performance.\textsuperscript{46}

Benefits with iron supplementation for marginally iron-depleted athletes were observed in other double-blind trials as well.\textsuperscript{127,128} However, several other studies failed to find significant improvements.\textsuperscript{129-131} These contradictory results suggest that the benefits of iron supplements for nonanemic, iron-deficient athletes is small at most.

For more information, including dosage and safety issues, see the full \textit{Iron} article.

**Colostrum**

Colostrum is the fluid that new mothers’ breasts produce during the first day or two after birth. Colostrum contains growth factors, such as IGF-1, that could enhance muscle development, and on this basis, it has been tried as a sports supplement.

An 8-week, double-blind study found that use of colostrum enhanced sprinting performance.\textsuperscript{132} Other double-blind studies found improvements in rowing performance and vertical jump, respectively.\textsuperscript{133}

In addition, a small double-blind study found that colostrum, as compared to whey protein, increased lean mass in healthy men and women undergoing aerobic and resistance training.\textsuperscript{47} However, no improvements in performance were seen in this trial.

Finally, in a double-blind, placebo-controlled study, use of colostrum over an 8-week training period did not improve performance on an exercise-to-exhaustion test; however, it did improve performance on a repeat bout 20
Interestingly, research suggests that the growth factor IGF-1 in colostrum is not directly absorbed into the body, yet consumption of colostrum nonetheless increases IGF-1 levels in the blood, perhaps by stimulating its natural release.

For more information, including dosage and safety issues, see the full Colostrum article.

**Pyruvate**

**Pyruvate**, also called dihydroxyacetone pyruvate (DHAP), supplies the body with pyruvic acid, a natural compound that plays important roles in the manufacture and use of energy. Pyruvate supplements have become popular with bodybuilders and other athletes based on slim evidence that pyruvate can improve body composition. However, at the present time, the evidence regarding pyruvate as an ergogenic aid is weak and contradictory at best. One study failed to find that pyruvate supplements improved body composition or exercise performance; furthermore, pyruvate appeared to negate the beneficial effect of exercise on cholesterol profile.

For more information, including dosage and safety issues, see the full Pyruvate article.

**Policosanol**

Policosanol is a mixture of waxy substances manufactured from sugarcane. It contains octacosanol, which is also made from wheat germ oil. Both are marketed as performance-enhancing dietary supplements said to increase muscle strength and endurance and improve reaction time and stamina. However, the only evidence for policosanol as a performance enhancer comes from one small double-blind trial with marginal results.

**Phosphatidylserine**

Phosphatidylserine (PS) is a phospholipid and a major component of cell membranes. Good evidence suggests that PS can improve mental function, especially in the elderly. However, PS has also been marketed as a sports supplement, said to help bodybuilders and power athletes develop larger and stronger muscles. This claim is based on modest evidence indicating that PS slows the release of cortisol following heavy exercise. Cortisol is a hormone that causes muscle tissue to break down. For reasons that are unclear, the body produces increased levels of cortisol after heavy exercise. Strength athletes who believe natural cortisol release works against their efforts to rapidly build muscle mass hope that PS will help them advance more quickly. However, only two double-blind, placebo-controlled studies of PS as a sports supplement have been reported, and neither one found effects on cortisol levels. Of these small trials, one found a possible ergogenic benefit, and the other did not.

Another study evaluated use of phosphatidylserine for improving the performance of golfers. While improvement in perceived stress levels failed to reach statistical significance, participants who were given phosphatidylserine did tee-off successfully at a greater rate than those given placebo.

For more information, including dosage and safety issues, see the full Phosphatidylserine article.

**Branched-chain Amino Acids: Leucine, Isoleucine, and Valine**

Amino acids are molecules that form proteins when joined together. Three of them—leucine, isoleucine, and valine—are called branched-chain amino acids (BCAAs), describing the shape of the molecules. Muscles have a particularly high BCAA content.

Both strength training and endurance exercise use greater amounts of BCAAs than normal daily activities, perhaps increasing an athlete's need for dietary intake of these amino acids. Sports such as mountaineering and skiing may cause even greater depletion of BCAAs because of metabolic changes that occur at higher altitudes.
Athletes have tried BCAA supplements to build muscle, improve performance, postpone fatigue, and cure overtraining syndrome (prolonged fatigue and other symptoms caused by excessive exercise). However, most of the evidence suggests that BCAAs are not helpful for these purposes. 62-69,155

Whey protein is rich in BCAAs, and on this basis, it has also been proposed as a bodybuilding aid. However, there is little evidence that whey protein is more effective for this purpose than any other protein. One small double-blind study found evidence that both casein and whey protein were more effective than placebo at promoting muscle growth after exercise, but whey was no more effective than the far less expensive casein. 156 Another study failed to find benefits with combined whey and soy protein supplementation. 174 However, a single small study did find ergogenic benefits with whey as compared to casein. 155

For more information, including dosage and safety issues, see the full Branched-chain Amino Acids article.

Other Amino Acids

Besides BCAAs, athletes use a number of other amino acids, sometimes individually and sometimes in combination. Amino acids believed by some to have ergogenic effects include arginine, glutamine, and ornithine (ornithine and glutamine combined form ornithine alpha-ketoglutarate, or OKG), as well as the branched-chain amino acids leucine, isoleucine, and valine, discussed above.

However, evidence supporting the use of amino acids as ergogenic aids is sparse to nonexistent. The few clinical trials performed generally don't show positive results. 69,70-72

Carnitine

Carnitine, a substance closely related to amino acids, is used by the body to convert fat into energy. Even though the body can manufacture all it needs, supplemental carnitine could, in theory, improve the ability of certain tissues to produce energy, leading to its promotion as a sports performance enhancer. To date, however, there is no meaningful evidence that this is the case. 187

Chromium

The mineral chromium has been sold as a "fat burner" and is also said to help build muscle tissue. However, studies evaluating its benefits as a performance enhancer or an aid to bodybuilding have yielded almost entirely negative results. 73-82

Coenzyme Q10

Coenzyme Q10 (CoQ10 ubiquinone) is a natural substance that plays a fundamental role in the mitochondria, the parts of the cell that produce energy from food. On this basis, CoQ 10 has been proposed as a performance enhancer for athletes. However, most clinical trials have found no significant improvement with CoQ 10. 83-89,157

For more information, including dosage and safety issues, see the full Coenzyme Q10 article.

Inosine

Inosine is an important chemical found throughout the body. It plays many roles, one of which is helping to make ATP, the body's main form of usable energy. Based primarily on this fact, inosine supplements have been proposed as an energy booster for athletes. However, most of the available evidence suggests that it doesn't work. 90-94

For more information, including dosage and safety issues, see the full Inosine article.

Ribose
Ribose is a carbohydrate that is also vital for the manufacture of ATP. Ribose has shown some promise for improving exercise capacity in people with certain enzyme deficiencies and other rare conditions that cause muscle pain during exertion. On this basis, it has been touted as an athletic performance enhancer; however, six small double-blind, placebo-controlled trials in humans failed to find any benefit. In one of these studies, dextrose (a form of ordinary sugar), proved effective while ribose did not.

For more information, including dosage and safety issues, see the full Ribose article.

**Gamma Oryzanol**

Very preliminary evidence suggests that gamma oryzanol, a substance derived from rice bran oil, may increase endorphin release and aid muscle development. These findings have created interest in using gamma oryzanol as a sports supplement. However, a 9-week, double-blind, placebo-controlled trial of 22 weight-trained males found no difference between placebo or 500 mg daily of gamma oryzanol in terms of performance, body composition, or hormone levels.

For more information, including dosage and safety issues, see the full Gamma Oryzanol article.

**Trimethylglycine**

Trimethylglycine (TMG) is a naturally occurring compound that may help to prevent atherosclerosis and is, therefore, sometimes taken as a supplement. In the course of its metabolism in the body, TMG is turned into another substance, dimethylglycine (DMG).

In Russia, DMG is used extensively as an athletic performance enhancer, and it has recently become popular among American athletes. TMG is cheaper, and it may have the same effects as DMG as it changes into DMG in the body. However, there is no evidence that DMG is effective, and some evidence that it is not.

For more information, including dosage and safety issues, see the full Trimethylglycine article.

**DHEA**

Athletes have used DHEA on the belief that (like phosphatidylserine) it might limit the body's response to cortisol and thereby cause an increase in muscle tissue growth. However, study results have conflicted on whether or not DHEA really interferes with cortisol. Furthermore, studies of DHEA as an aid to increasing muscle mass or enhancing sports performance have produced mixed results at best.

For more information, including dosage and safety issues, see the full DHEA article.

**Tribulus Terrestris**

*Tribulus terrestris* is a tropical plant with a long history of medicinal use. It has been tried for low libido in both men and women, and for impotence and female infertility.

One theory regarding how *T. terrestris* might help with sexual problems is that a component from the plant called protodioscine is converted to the hormone DHEA in our bodies. DHEA is used by the body as a building block for both testosterone and estrogen (as well as other hormones). This finding has led bodybuilders and strength athletes to try *T. terrestris* for increasing muscular development. So far, however, the scientific evidence seems to be against it. This is not surprising because DHEA itself has not been found effective as a sports supplement.

One study involving 15 men compared the effects of *T. terrestris* (3.21 mg per kilogram of body weight—for example, 292 mg daily for a 200-pound man) against placebo on body composition and endurance among men engaged in resistance training. At the end of the 8-week study, the only significant difference between the treatment and placebo groups was that the placebo group showed greater gains in endurance.
Another double-blind, placebo-controlled study, which enrolled 22 athletes and followed them for five weeks, failed to find benefit. The dose used in this trial was fixed at 450 mg daily for all participants.

For more information, including dosage and safety issues, see the full *Tribulus terrestris* article.

**Phosphate**

Because phosphate plays a fundamental role in the body's energy-producing pathways, it has been suggested that taking high doses of phosphate (phosphate loading) prior to athletic activities might enhance performance. Phosphate-containing chemicals are also part of the process that allows oxygen release from hemoglobin, and this too has intrigued researchers looking for ergogenic aids. However, while some studies have found that phosphate loading improves maximum oxygen utilization, others have not. Flaws in study design cast doubt on the positive results.\(^{104,105,171,172}\)

For more information, including dosage and safety issues, see the full *Phosphorus* article.

**Commercial Preparations**

A small double-blind study of a mixture of various herbs and supplements marketed as SPORT® found no evidence that it can improve sports performance in trained athletes.\(^{111}\)

**Stimulants: Ma Huang and Caffeine**

A number of plant-derived stimulants are used by some athletes to improve their performance, including ephedrine from the Chinese herb *ma huang* (also called ephedra) and caffeine from coffee, tea, *maté*, cola, or guarana (a plant native to South America). Both ephedrine and caffeine are central nervous system stimulants. Caffeine also appears to change the way your body burns calories, possibly allowing it to burn fats first and preserve muscle glycogen for later in the competition—sort of like "saving the best for last."\(^{112}\)

Caffeine does appear to improve performance during endurance-type exercises.\(^{112}\)

**Note:** The International Olympic Committee has set a tolerance limit for caffeine in the urine at 12 mcg/ml. If you're competing in a sport that follows similar regulations, you may want to have a cup of coffee or tea, but don't drink the whole pot.

Ephedrine's value in enhancing sports performance has not been established; at the same time, there are serious safety issues associated with its use.\(^{138}\) (See the Safety Issues section in the full article on *Ephedra.*) Some sports federations have determined that specific amounts of ephedrine in an athlete's system are grounds for disqualification.

**Other**

One small double-blind trial found that use of the herb *Rhodiola rosea* improved endurance exercise performance.\(^{162}\) However, another study failed to find benefit with a combination of *cordyceps* and rhodiola.\(^{163}\)

A variety of antioxidants have been proposed for enhancing recovery after heavy exercise. One study found weak evidence that a combination of vitamin E (400 mg daily) and vitamin C (1,000 mg daily) taken for 3 weeks can improve aerobic performance.\(^{185}\)

Heavy exercise causes increased calcium loss through sweat, and the body does not compensate for this by reducing calcium loss in the urine.\(^{180}\) The result can be a net calcium loss great enough so that it presents health concerns for menopausal women, who are already at risk for osteoporosis. One study found that use of an inexpensive calcium supplement (calcium carbonate), taken at a dose of 400 mg twice daily, is sufficient to offset this loss.\(^{180}\)

A small study found endurance exercise benefits with the herb *Panax notoginseng*.\(^{164}\)
One small trial suggests that acupuncture may enhance peak performance capacity. Weak evidence hints that arachidonic acid supplements might enhance response to resistance training. Use of a low-glycemic-index snack three hours prior to endurance running may be more helpful than a high-glycemic index (carbohydrate) snack. However, another study failed to find benefit. Galactose is a type of sugar that the body combines with glucose to create lactose (“milk sugar”). For various theoretical reasons, it has been hypothesized that use of galactose might enhance endurance exercise performance. However, the one small study designed to test this hypothesis found, instead, that consumption of galactose prior to endurance exercise actually proved detrimental. A small, double-blind study failed to find any performance or training-enhancing benefits with a newly marketed silicate product. Astaxanthin, fish oil, N-acetylcysteine (NAC), soy isoflavones, and tyrosine have also failed to show benefit in preliminary trials. Numerous other natural substances have been marketed as ergogenic aids, despite essentially an absolute absence of evidence that they help, including cordyceps, Cystoseira canariensis, deer antler, ipriflavone, lipoic acid, methoxyisoflavone, NADH, and suma. One study found that L-citrulline, another purported ergogenic aid, actually decreases exercise capacity. Many websites advertise products that they claim act like human growth hormone, often called HGH enhancers. However, these products are entirely speculative because there are no natural treatments proven to raise human growth hormone levels. Similarly, there are no herbs or supplements known to act as “natural anabolic steroids.” (See also the discussion of androstenedione in the Not Recommended Treatments section.) One small study failed to find benefit with a liquid multivitamin/mineral supplement. The amino acid beta-alanine is said to raise levels of carnosine, which in turn is hypothesized to enhance performance in athletes undergoing resistance training. However, a double blind study of 26 athletes failed to find benefit with 6 g of alanine daily. Not Recommended Treatments Three commonly recommended supplements fall in the "not recommended for athletes" category: vanadium, boron, and androstenedione. The mineral vanadium has been suggested for use by bodybuilders based on its effects on insulin, but there is no evidence that it helps. A double-blind, placebo-controlled study involving 31 weight-trained athletes found no benefit of supplementation at more than 1,000 times the nutritional dose. Furthermore, there are serious safety concerns about taking vanadium at such high doses. See the full article on Vanadium for more information. The mineral boron has been proposed as a sports supplement because it is thought to increase testosterone levels. However, studies performed thus far have failed to provide meaningful evidence that it helps increase muscle mass or enhances performance. Furthermore, clinical studies suggest that boron supplementation is more likely to increase estrogen than testosterone. Increased estrogen is not likely to have a sports performance benefit in men, while in women it might increase risk of breast cancer. Therefore, we don't recommend taking supplemental boron as a sports supplement. See the full article on boron for more information. The hormone androstenedione is said to enhance athletic performance and strength by increasing testosterone production, thereby building muscle. However, in double-blind studies, when androstenedione was given to men, it neither altered total testosterone levels, nor improved sports performance, strength, or lean body mass.
It did, however, increase estrogen levels, an effect that would not be considered favorable. Interestingly, androstenedione does appear to raise testosterone levels in women, but it is not clear whether this would produce favorable results. For more information, see the full Androstenedione article.

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