Human diseases transmitted by parasitic bugs

by

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There are only two groups of bugs (Hemiptera), the family Cimicidae, or bedbugs, and the subfamily Triatominae, or cone-nosed bugs, which contain members that frequently or habitually suck blood from human beings, and these are, therefore, the only members of the order that need be considered from the standpoint of transmission of human disease.

The Cimicidae comprise a number of genera and species of bloodsucking bugs, but only two members of the typical genus, Cimex, C. lectularius and C. hemipterus, the former in temperate climates and the latter in the tropics, habitually live in human habitations and bite man. Leptocimex boueti is reported to be a human parasite in French Guinea, and Haematosiphon inodora of Southern United States and Mexico, where it is often a pest in poultry houses, sometimes invades human habitations. Occasionally cimicid parasites of bats and swallows also invade houses, but rarely if ever suck human blood.

On a priori grounds Cimex lectularius and C. hemipterus would appear to be eminently adapted for transmission of human disease, and they have been under constant suspicion. With or without reason they have been suspected and experimented with in connection with a large number of human infections, including some caused by helminths (filariasis), Protozoa (kala-azar, Chagas' disease), rickettsias (typhus, spotted fever, Q fever), bacteria (plague, tularemia, leprosy, typhoid, brucellosis), spirochetes (relapsing fever, Weil's disease), and viruses (yellow fever, encephalomyelitis and poliomyelitis). In spite of all this suspicion, and of extensive experimental work, there has not yet been produced evidence that bedbugs are more than occasional or accidental transmitters of any human disease. A general review of the role of bedbugs as vectors of disease was given by Zumpt in 1940 (89).

Bedbugs are, however, conservators of a great variety of infectious agents, harboring them in their bodies of even voiding them in their feces for many

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days or even for life. Among organisms known to survive in bedbugs in this manner are *Leishmania donovani* (67), *Schizotrypanum cruzi* (5), *Pasteurella pestis* (2), *P. tularensis* (18), *Brucella abortus* (77), *Borrelia recurrentis* (42), *Leptospira icterohaemorrhagiae* (4), *Rickettsia prowazeki* (62), *Dermacentrotrix rickettsi* (53) and yellow fever virus (60). About the last two, however, there is some uncertainty, since Monteiro (61) and Kumm & Frbishier (48), by injecting crushed bugs into animals, were able to transmit spotted fever and yellow fever for only 1 or 2 days after an infective meal. Castañeda & Zinsser (11) found that the rickettsia of the Mexican typhus may survive for 10 days in the gut of *Cimex lectularius*, but failed to transmit the infection by the bite or the feces of infected bugs.

It has been proved that *Schizotrypanum cruzi* can develop experimentally in several species of bedbugs, such as *Cimex lectularius* (5), *C. hemipterus* (6), *C. hirudinis* (8), *Cimex sp.* (10), *C. stadleri* (10), *Leptocimex boueti* (5) and *Haematosiphon inodora* (58). Infected *Cimex lectularius* have been found in natural conditions in Argentina, in the bed of a child with acute Chagas disease, but no more infected bugs were found in the same place 3 and 4 months after the acute period of the patient’s infection was over (56). In other countries naturally infected bedbugs have never been encountered and it is generally believed that these insects do not play any rôle as natural carriers of Chagas disease. Blacklock (3) concluded from his experiences that although *C. lectularius* may keep infective trypanosomes for a long time, the transmission of *S. cruzi* to animals usually does not occur, even under the most favorable conditions.

*Latrocinex spectans* and *Cimex limai* captured in tree-holes in the Marajó Island (Pará, Brazil), where they lived in association with infected triatomid bugs (*Cavernicola pilosa*) and infected bats, were not infected with *Schizotrypanum* (38).

The only bugs important as human disease transmitting agents, therefore, are the cone-nosed bugs which comprise the subfamily *Triatominae* of the family *Reduviidae*. Some authors have elevated this group to the rank of a family, but Costa Lima (15), Usinger (79) and Lent (50) consider this view untenable. The medical importance of the triatomids was first demonstrated by Carlos Chagas (12) in Brazil in 1909, when he discovered that they are the vectors of *Schizotrypanum cruzi* Chagas, 1909, a protozoan flagellate that causes the disease that now bears his name.

There are nearly one hundred species of *Triatominae*, belonging to several tribes and genera, but the species that are of importance in the transmission
of Chagas' disease are members of the tribes Triatomini (genera Triatoma and Panstrongylus) and Rhodniini (genus Rhodnius). The great majority of the triatomids are exclusively American and are widely distributed in this hemisphere (fig. 1). There are a few extra-American species and one tropicopolitan species, Triatoma rubrofasciata.

All of the Triatominae are bloodsuckers throughout their lives, and usually live in the burrows, nests or homes of the animals on which they feed. They hide away in the daytime and feed at night. They become very engorged after a full meal, and may not feed again for several days; they are capable of resisting starvation for several months. They require blood for ecdysis and oviposition. The duration of life is long, and varies according to the species and to environmental conditions; some species require two full years to complete the life cycle. For details of the life cycle of some North American species and references to work on their life cycles, see Usinger (80). The egg, nymph and adult stages of several South American species are shown in fig. 2.

The winged adults fly at night, nondomesticated species frequently entering houses temporarily, but long enough to suck human blood. The nymphs of such species, however, also may enter houses, and sometimes remain for a long time.

Most triatomids frequent the burrows or nests of wild animals, such as rodents, armadillos, and opossums. Some species have decided host preferences, certain ones being constantly associated with armadillos (Panstrongylus geniculatus), bats (genus Cavernicola), opossums (genus Parabehmiinus) and birds (genus Psammeleotes). Nearly all of the species found in the United States appear to be primarily inhabitants of the nests of various species of woodrats (Neotoma). Some species show much less host specificity than others. Some, for instance Rhodnius prolixus in South and Central America, Panstrongylus megistus, Triatoma infestans and Triatoma brasiiliensis in South America, are domestic species that habitually live in human habitations and suck human blood. Nearly all of the species in the tribes Triatomini and Rhodniini, however, which we are concerned here, are not averse to feeding on other animals than the ones with which they are usually associated if opportunity is offered. Nearly all species will willingly bite dogs, cats, monkeys, birds, laboratory animals or man if given the opportunity. For this reason sporadic human cases of Chagas' disease may occur even in localities where none of the local species of Triatoma habitually live in association with man.
Another important habit of the bugs, from the standpoint of transmission of Chagas’ disease, is their tendency to defecate during or after engorgement, thus contaminating the bite, or the mucous membranes around the eyes near which the bugs frequently bite, with their infected feces.

As in the case of bedbugs, triatomines have been under suspicion, and experimented with, as possible vectors of infections caused by viruses, rickettsias, bacteria and protozoa. Davis (19) claims to have obtained the mechanical transmission of the yellow fever virus with Panstrongylus megistus, and Antunes (1) thinks it possible under natural conditions by means of Rhodnius prolixus in Colombia. The survival of murine typhus rickettsia has been observed for 16 days in Triatoma infestans (83) and for at least 33 days in T. barberi (81). Nauck & Zumpt (62) did not succeed in transmitting epidemic typhus through the bite of T. rubrofasciata, although this insect may harbor living rickettsias for some time, while Veintemillas (82) claims to have obtained its transmission by T. infestans, although he does not give reference to the experiments on which this statement was based. The spotted fever rickettsia does not remain alive in the gut of several species of cone-nosed bugs more than a few days (37, 68). According to Liem (52), T. infestans may be conservator but not carrier, unless perhaps under exceptional circumstances, of several other pathogenic agents, such as Salmonella (132 days), Spirochaeta duttoni, and Leptospira icterohaemorrhagiae, but the bites of the bugs were never infective for normal susceptible animals. Mertens (59) reported that T. rubrofasciata may keep Pasteurella pestis in living condition for at least a month; the bite was not infective, but mechanical transmission was thought possible.

Thus far the cone-nosed bugs are known to be responsible for the transmission of two human protozoan parasites, viz.. Schizotrypanum cruzi Chagas, 1909, and Trypanosoma rangeli Tejera, 1920. It is worth remembering here that the tropicopolitan Triatoma rubrofasciata, besides harboring Schizotrypanum cruzi in Brazil, is also the carrier of Trypanosoma conorhini Donovan, 1909, a rat parasite that occurs in several continents, including South America (40).

Trypanosoma rangeli was first described in Venezuela by Tejera (75) in the gut of Rhodnius prolixus, and was named Trypanosoma or Crithidia rangeli. The first evidence that it was a human parasite was produced in 1943 by Dias & Torrealba (41), who found rangeli-like flagellates in clean R. prolixus that fed upon a child patient from Venezuela. However, these authors supposed that the flagellates were inconstant or atypical developmental forms of a human Schizotrypanum, because only cruzi-like forms were
seen in clean bugs fed upon animals inoculated with gut contents of rangeli-infected Rhodnius, and in cultures obtained from them. Pifano and co-workers (69, 70) later correctly suggested that the child on which the R. prolixus were fed had a mixed S. cruzi and T. rangeli infection. These authors have found several cases of human infection by T. rangeli in Venezuela, and also established that the dog is a natural reservoir of the parasite. They maintain that Trypanosoma guatemalensis found in man and in R. prolixus in Guatemala by De León (51) is the same species as T. rangeli described by Tejera (75) in Venezuela. R. prolixus is also infected with T. rangeli in Colombia (78, 72) and possibly in Mexico (10). So far it has not been established whether T. rangeli is a pathogenic organism or not. Animal inoculations so far have been unsuccessful (69, 70), except for young mice inoculated with cultures (Pifano, personal communication to E.D.).

Schizotrypanum cruzi, the cause of Chagas disease or schizotrypanosis is quite different in morphology and life-cycle from the ordinary trypanosomes; it possesses a leishmania intracellular stage in the vertebrate host and should, in the view of one of us (24, 27), and of many other workers, be maintained in a separate genus of the family Trypanosomidae, distinct from the genus Trypanosoma. The fact that another human trypanosomiasis is now known in this continent is one more argument favouring the name schizotrypanosis, based on the validity of the genus Schizotrypanum, for Chagas' disease, substituting the habitually used name of American trypanosomiasis.

A great deal of information is now available on Chagas' disease and it has been recognized that this disease is a very important social and public health problem in South America. The disease has been found in man only in the Western Hemisphere, but monkeys from the Orient have been found infected with S. cruzi (54). Since Schizotrypanum cruzi, unlike most trypanosomes, is capable of developing in a remarkable variety of arthropod hosts including, besides triatomids, bedbugs, Melophagus (73), various species of ticks, and even the body cavity of a caterpillar (47), it is not surprising that there is little specificity with respect to the species of triatomids which are capable of harboring this organism. At least 36 species of triatomids have been found naturally infected with S. cruzi, and experimental infections have been successful for all species with which it has been tried. A number of authors, however, have found different degrees of susceptibility in different species of bugs, for which reason the senior author has recommended the use of local vectors for xenodiagnosis (29). In Brazil, for instance, three Brazilian triatomids (Panstrongylus megistus, Triatoma infestans, T. sordida) were found to be distinctly more susceptible to the Brazilian strain of S. cruzi than was
Rhodnius prolixus (28), although the latter is the principal carrier of the disease in Venezuela. On the other hand, R. prolixus proved to be more susceptible to the development of two Venezuelan strains than were P. megistus and T. infestans (30). Similar differences between R. prolixus and R. pictipes as compared with T. rubrofasciata have been reported in French Guiana (43).

There is also some evidence that various strains of S. cruzi differ in their virulence for laboratory animals, and that this difference seems sometimes to be associated with the species of vector. Mazzotti (57), for instance, reported a very high virulence for a strain obtained from Triatoma barberi in Mexico, low virulence in a strain from Dipetalogaster maximus, and intermediate degrees of virulence in strains from other species. While several authors have reported the high virulence of certain South American strains of S. cruzi, low degrees of virulence have been reported for strains from bugs in the United States (63, 64, 85).

Triatomids ordinarily acquire S. cruzi infections by feeding on infected animals or man. Within 24 hours after an infective meal trypanosomes may pass into the intestinal portion of the midgut, where they transform into crithidia and multiply abundantly (fig. 9, A).

Eventually crithidial forms pass to the rectum where small ones are found attached to the epithelium (fig. 9, B). In the rectum they give rise to the metacyclic trypanosomes which are the infective forms. They appear about the sixth day in nymphs but not until the tenth to fifteenth day in adults (23). Although sometimes flagellates are found in the Malpighian tubes (20), normally the infection in the bugs is confined to the alimentary canal, so no transovarial transmission occurs. However, if the flagellates, by inoculation (21) or by accident, gain access to the body cavity of the bugs they persist and multiply there. Wood (87) believed that these abnormal haemocele infections might have some special significance in transmission of the infection in Nature.

A number of species of bugs have been reported to be cannibalistic (7, 76, 25), i.e., to suck blood or haemolymph from other engorged bugs, which would be a means of spreading the infection directly from bug to bug. However, this phenomenon has never been observed under natural conditions and Usinger (80) never noticed it in his colonies or in jars where hundreds of bugs were fed together. Direct bug-to-bug transmission might also result from coprophagy (7) or through the egg (55), but the only known references to these possibilities never could be confirmed. It is probable, therefore, that in Nature the bugs become infected only from reservoir vertebrate hosts, and that the incidence of infection in the bugs is indicative of its prevalence in the
vertebrates on which the bugs feed (76, 25). In this connection it is interesting that Wood (84) collected triatomes (*T. protracta*) from various nests in California and found that all or none of the insects from a given nest were infected, a fact that indicates that all bugs from a nest which had harbored an infected animal had fed upon that animal; and that Packchanian (64) found 42 *Triatoma heidemanni* (= *T. lectularius*) nymphs collected from five homes in Temple, Texas, free of infection, whereas two lots collected from a cotton field, comprising 6 adults and 44 nymphs, were all infected.

*Schizotrypanum cruzi* is a flagellate with a type of development in the "posterior station" of the insect host, the salivary glands of which are not invaded. So the parasite is transmitted by the "contaminative" method, i.e., human infection results from contamination of the bites by the feces of the bugs when these are deposited towards the end of a feeding, or by rubbing the feces into the eyes or on to other mucous membranes or the skin. Hoare (46) has made a critical review on the transmission of Chagas' disease. In animals this method of transmission is supplemented by the eating of infected bugs, or by licking areas of skin which have been bitten and where the feces of bugs have been deposited. Animals may also become infected by eating infected vertebrates; cats have been experimentally infected when they were fed on infected mice (31).

Since the trypanosomes are almost as indiscriminate with respect to their vertebrate hosts as they are to their arthropod hosts, triatomids may become infected from any of the mammalian hosts with which they are associated, and may then pass the infection on to other hosts of the same species or of other species. Man is liable to infection from the bites of "wild" species of bugs which have acquired their trypanosomes from wood rats, armadillos, opossums, etc., when these bugs subsequently invade his domiciles, or when he is accidentally bitten by the bugs outdoors. In the case of "domestic" species, on the other hand, the principal hosts from which the bugs acquire their trypanosomes, other than man himself, are mainly dogs and cats. Brumpt, Mazzotti & Brumpt (10) found that even sheep, goats and pigs are susceptible to experimental infections, and think that in Latin America, where pigs are very common around rural habitations, these animals may constitute a reservoir of infection, a view later confirmed by C. Pinto (71) who found *Sus scrofa domesticus* naturally infected in Rio Grande do Sul, Brazil.

A comparatively few species of triatomids have become "domestic", adapted to living by preference in human habitations and habitually biting human beings. Examples of such species are *Triatoma infestans*, widely dis-
tributed in the central and southern parts of South America; Panstrongylus megistus of Brazil; Rhodnius prolixus of northern South America and Central America. Other species that frequently breed in houses are Triatoma brasi-
lensiis, T. sordida, T. maculata in South America; T. phyllosoma, T. palli-dipennis and T. dimidiata in Mexico and Central America. T. dimidiata is also the principal vector in Ecuador. Panstrongylus geniculatus is frequently
found in armadillo burrows, (13) in the adult stage sometimes in houses; it is considered to be the principal vector of Chagas’ disease in Panama (14).

In the United States there are ten species naturally infected (T. gers-
taeckeri, T. lectularius, T. longipes, T. neotomae, T. protracta, T. protracta
woodi, T. rubida, T. sanguisuga (16), T. sanguisuga ambiguus, T. uhleri) and
two others experimentally infected; nearly all have been found at times in
houses or tents, and some, e.g. T. protracta (85), T. longipes (86), and T.
gertsaeckeri (63), so frequently and in such abundance as to be nuisances.

Although triatomids infected with S. cruzi occur throughout the warm
parts of the Western Hemisphere from southern United States to Chile and
Argentina, human cases of Chagas’ disease occur frequently only in areas
where the “domestic” species of triatomids are abundant. Infection rates
running from 5 to over 40% (table I). The infection has so far not been repor-


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*) Data summarized from Dias and Laranja’s (35) tables 1-2-3.
ted from Dutch or British Guiana, though it occurs in French Guiana. In Central America the disease is known in Panama, Qèsta Rica, Salvador and Guatemala. In North America, however, only a few cases have been reported from Mexico and not from the United States, where, however, various animal reservoirs of S. cruzi have been found (84, 65).

Davis & Sullivan (17) have examined 1909 samples of human sera, 568 of which were from people living in rural areas of Texas, and obtained only one positive complement-fixation reaction; the positive serum was from a boy whose blood was later inoculated into a Peromyscus mouse with negative result.

This lack of correspondence of human cases of schizotrypanosiosis with the frequency of infection with S. cruzi in triatomid bugs is undoubtedly due to the interaction of a number of factors. One of the most important factors is the presence and abundance of domestic species of bugs, such as P. megistus, T. infestans and R. prolixus. The frequency of infection within the range of these three species is largely determined by the structure and sanitary condition of human habitations. The primitive, insanitary dwellings that prevail in most rural districts of Latin America, usually made of dried mud and covered with thatched roofs (fig. 3-8) provide excellent places for harboring and breeding domestic triatomids. Several hundreds or even thousands of bugs may sometimes be found in a single hut (34). It is, therefore, not surprising that Chaqas' disease is often very common, as indicated in Table I. There may be millions of cases in Latin America.

Outside the range of the "domestic" species of triatomids, however, there must be other factors concerned besides frequency of bites. In Mexico, where human infections are apparently rare, and where there are several more or less "domestic" species of bugs, and in the United States, where no natural human case has yet been observed, houses are frequently invaded by "wild" species of bugs, and bites of human beings by infected bugs must certainly be of frequent occurrence in some localities. One explanation that suggests itself is that in areas where domestic species of triatomids do not occur the trypanosomes, although morphologically like those causing Chagas' disease in South America, might be of low virulence for man, or even non-infective, a condition that would be analogous to the Trypanosoma brucei-Trypanosoma rhodesiense situation in Africa. This explanation, however, seems untenable since an accidental human case was produced in Paris by trypanosomes derived from a Triatoma pallidipennis collected from a woodrat nest in Mexico (45), and an experimental human case was produced by Packchanian (66) by
ocular inoculation of a Texas strain of *S. cruzi* from *Triatoma lectularius* (= *T. heidemanni*). It is possible, however, that the North American strains have lower virulence for man as well as for laboratory animals as compared with South American strains, and that in well-nourished, healthy individuals the infection may be so light as to be easily overlooked.

It is probable, however, that another factor may play an important part in determining the frequency of human infection, namely, difference in habits of different species of bugs with respect to defecation during or at the end of a meal. This was suggested by Brumpt in 1939 (9). Some Triatomids, including the domestic South American species are quick to defecate towards the conclusion of a meal, whereas others, notably *Triatoma protracta*, usually defecate later, and thus are far less likely to contaminate their biter or the mucous membranes in the vicinity of the bites. It may be, too, that the non-domesticated species are less prone to bite in the vicinity of the eyes, and also, since they are in a more or less strange environment, may be more easily disturbed during a meal, and therefore less likely to defecate before moving away. It is also probable that in many regions there may only appear to be lack of correspondence between human infection with triatomid infection for lack of an adequate search of human cases, as was formerly the situation in Argentina, Uruguay and other countries.

It is evident that a high percentage of human cases are infected through the eyes, for many acute cases show the “eye sign” or “Romaña’s sign” (fig. 10). Local swelling in the skin at the portal of entry of the infection is also common (fig. 11). In 100 cases from Bambuí, Minas Gerais, Brazil, 77 had signs of portal of entry, 48 of which were ocular and 29 cutaneous (Dias and Laranja, 35). The symptoms, signs and clinical course of the disease have been recently reviewed in several papers by the senior author and his colleagues (35, 36, 49), and a good summary in English was prepared by Yorke (88) in 1937.

During the first weeks of infection trypanosomes can usually be found easily in the peripheral blood by direct examination, but then they begin to disappear and later on can be detected only by indirect laboratory methods such as *xenodiagnosis*, animal inoculation, and haemoculture. The success of *xenodiagnosis* proves that chronic cases may be still infective for bugs long after the parasites have ceased to be demonstrable microscopically in the blood, and after all acute symptoms have disappeared. One of us (22, 26) obtained positive *xenodiagnosis* in chronic patients that had left the endemic districts since 12 and 16 years before. However, not all bugs feeding on
patients become infected. Freitas (44) got only 212 (20.6%) of positives among 1025 bugs fed on known cases, and one patient was tested 14 times. Of 32 patients mentioned as being tested three times, 17 were positive on the first test, 9 on the second and the other 6 on the third. Complete (parasitological) cure of the disease does not seem to occur; the infection goes into the chronic period, which probably lasts for life. So far there is no effective treatment for Chagas' disease.

Prophylaxis is based on the suppression of cone-nosed bugs in houses by destruction of the bugs by means of insecticidal applications, and improvement and protection of rural dwellings. Health education is very important (32). Up to the present benzene hexachloride (Gammexane) has proved to be the best insecticide for triatomids. House disinfection may be effectively accomplished by benzene hexachloride sprays followed by the application of pyrethrum powders (39).

For the first time a town in Brazil has been freed from triatomid bugs; this was done by repeated applications of insecticides in the houses. This town is Bambui, Minas Gerais, a typical focus of "domestic" infection (33), where no new acute cases of Chagas' disease have occurred for nearly five years.

Recently (74) smoke generators containing benzene hexachloride, sulphur and ammonium nitrate have been developed which burn for about one minute giving forth an abundance of white smoke which deposits on all surfaces a fine whitish powder with the properties of benzene hexachloride. The smoke penetrates into cracks and crannies that spray treatments fail to reach, and all triatomids as well other arthropod pests are dead within a few days. However, in Brazil experiences with smoke generators have given a rather poor result.

EXPLANATION OF THE FIGURES

Fig. 1 — Geographic distribution of genera and species of triatomid bugs. After Hase, A., 1932, fig. 15 (Brobxachtungen an venezolanischen Triatoma-Arten, sowie zur allgemeinen Kenntniss der Familie Triatomidae (Hemipt-Heteropt.), Zeitschr. f. Parasitenkunde 4 : 585-652.

Fig. 2 — Stages in the life cycle of four species of cone-nosed bugs (Panstrongylus megistus, Triatoma infestans, T. sordida and Rhodnius prolíxus). Eggs, three nymphal stages and adults.
Fig. 3 — Human dwelling suitable for breeding of triatomid bugs. Mud hut. Minas Gerais, Brazil.

Fig. 4 — Human dwelling suitable for breeding of triatomid bugs. "Rancho de capim e taquara". Minas Gerais, Brazil.

Fig. 5 — Human dwelling suitable for breeding of triatomid bugs. Mud. hut. Santiago del Estero., Argentina. Courtesy of Dr. C. Romaña.

Fig. 6 — Human dwelling suitable for the breeding of triatomid bugs. Adobe "rancho". Argentina. Courtesy of Dr. C. Romaña.

Fig. 7 — Human dwelling suitable for breeding of triatomid bugs. "Rancho de quincha". Argentina. Courtesy of Dr. C. Romaña.

Fig. 8 — Human dwelling suitable for breeding of triatomid bugs. Stone hut covered with thatched roof. Nuevo León, Mexico.

Fig. 9 — Evolution of forms of Schizotrypanum cruzi in the intestine of Panstrongylus megistus. A — Crithidia in the lumen of the tubular part of mid-gut. After Dias, 1934 (23), fig. 10. B — Flagellates attached to the epithelium of the rectum.

Fig. 10 — Ocular portal of entry of Chagas’ disease (eye sign).

Fig. 11 — Cutaneous portal of entry of Chagas’ disease (chagoma). After Diniz, O., 1945, "Aspecto dermatológico de um chagôma de inoculação", Brasil Méd. 59: 297-298.

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