

Hemiptera of Canada

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Academic editor: D. Langor | Received 10 May 2018 | Accepted 10 July 2018 | Published 24 January 2019

<http://zoobank.org/64A417ED-7BB4-4683-ADAA-191FACA22F24>

Citation: Foottit RG, Maw HEL, Kits JH, Scudder GGE (2019) Hemiptera of Canada. In: Langor DW, Sheffield CS (Eds) The Biota of Canada – A Biodiversity Assessment. Part 1: The Terrestrial Arthropods. ZooKeys 819: 277–290. <https://doi.org/10.3897/zookeys.819.26574>

Abstract

The Canadian Hemiptera (Sternorrhyncha, Auchenorrhyncha, and Heteroptera) fauna is reviewed, which currently comprises 4011 species, including 405 non-native species. DNA barcodes available for Canadian specimens are represented by 3275 BINs. The analysis was based on the most recent checklist of Hemiptera in Canada (Maw et al. 2000) and subsequent collection records, literature records and compilation of DNA barcode data. It is estimated that almost 600 additional species remain to be discovered among Canadian Hemiptera.

Keywords

Barcode Index Number (BIN), biodiversity assessment, Biota of Canada, DNA barcodes, Hemiptera, true bugs

The order Hemiptera, the true bugs, is a relatively large order. Worldwide there are an estimated 106,970 described species (Henry 2017, Bartlett et al. 2018, Hardy 2018). The recognised Canadian Hemiptera fauna (Table 1) has been greatly expanded since the review by Scudder (1979), with an increase of 937 species above the 3079 then known. The checklist of Canadian Hemiptera (Maw et al. 2000) provided comprehensive lists and distributions for all species recognised at that time. Here we present updated totals, including a number of additional unpublished records represented by

specimens in the Canadian National Collections of Insects, Arthropods and Nematodes (CNCI) in Ottawa. Gwiazdowski et al. (2015) presented a detailed analysis of all Hemipteran DNA barcodes available for the Canadian fauna.

A further 590 species are estimated to occur in the country, with the majority expected in the large families Aphididae, Cicadellidae, and Miridae. Estimates of the number of unrecorded species for the less diverse families is based mainly on known but undescribed species and presence of species in adjacent climatologically and ecologically similar parts of the United States, and known distributions of host plants. Molecular data and analysis of host plant usage provides evidence of additional cryptic diversity in the more speciose phytophagous groups. For some families, presence of unnamed clusters in the DNA barcode data suggests additional species, assuming that in most cases Barcode Index Numbers (BINs), as defined by Ratnasingham and Hebert (2013), correspond to one or more species (Gwiazdowski et al. 2015).

The classification used here follows Psyl'list (Ouvrard 2018) for Psylloidea, Aphid Species File (Favret 2018) for Aphidomorpha, ScaleNet (García Morales et al. 2016) for Coccoidea, Bartlett et al. (2018) for higher classification of Auchenorrhyncha, Bartlett et al. (2014) for species level delimitation in Fulgoromorpha, Dmitriev (2018) for species level delimitation in Cicadomorpha, and Henry (2017) for higher level classification of Heteroptera. There have been several changes in higher level classification since Scudder (1979). Homoptera, no longer recognised as a formal taxon, is now treated as two suborders, namely Sternorrhyncha and Auchenorrhyncha. Although not followed here, some authors (after Sorensen et al. 1995) separate the Auchenorrhyncha into suborders Clypeorrhyncha and Archaeorrhyncha. Among Sternorrhyncha, many new families of scale insects have been erected; species in Canada formerly included in Margarodidae are now dispersed among Matsucoccidae, Steingeliidae and Xylococcidae; Putoidae was formerly included in Pseudococcidae. Schemes for the subdivision of family Aphididae, such as that of Heie (1980) (and used in the Hemiptera checklist of Maw et al. 2000), have been proposed, but largely ignored in the absence of a clear consensus on the relationships among aphid subgroups. Within the Fulgoroidea, the Acanaloniidae, Dictyopharidae, and Kinnaridae are now recognised in Canada, with their species removed from the Issidae, Fulgoridae, and Cixiidae, respectively. The broadly constituted Cercopidae has been divided, with most Canadian species now placed in the Clastopteridae and Aphrophoridae. In the Heteroptera, most former lygaeid subfamilies have been given family status so that Lygaeidae of Scudder (1979) is now represented by eight families (Henry 1997); the further segregation of Ischnorhynchidae and Orsillidae (Sweet 2000) from Lygaeidae is not recognised here. Lyctocoridae and Lasiochilidae have been separated from Anthocoridae. On the other hand, Aradidae now includes Meziridae, Miridae includes Isometopidae, and Reduviidae includes Phymatidae and Ploiariidae.

The 419 non-native species of Hemiptera represents a significant proportion of the total fauna. In Aphididae, about 19% of the species are non-native. An overview of the non-native aphid fauna of North America was provided by Foottit et al. (2006) and updated by Skvarla et al. (2017). The non-native Heteroptera of Canada (about 7% of the total fauna) were treated by Scudder and Foottit (2006).

Sternorrhyncha

Worldwide, the Sternorrhyncha are represented by about 18,690 species (Hardy 2018), with about 2950 species in North America (approximate composite number based on Foottit et al. 2006, García Morales et al. 2016, Skvarla et al. 2017, Mallory 2018, Ouvrard and Martin 2018). Currently, 1120 species of Sternorrhyncha are known from Canada compared to 834 in 1979, and it is expected that a further 215 species will be eventually found in the country (Table 1).

In Canada, the Aphididae and Adelgidae are relatively well known. Foottit and Maw (1997, 2014) contributed syntheses of the Yukon and grassland faunas of Aphididae. Aphids and adelgids are well represented by DNA barcodes (Foottit et al. 2008, 2009a, b), and, in general, barcode diversity in these groups corresponds well to morphological species concepts. However, several currently recognised aphid species are represented by more than one BIN, as defined by Ratnasingham and Hebert (2013). In two such cases, subsequent morphological analysis and addition of other genetic loci has resulted in the recognition of new species (Foottit et al. 2010, Foottit and Maw 2018). Conversely, members of several aphid species groups are not distinguishable by COI sequence divergence (Foottit et al. 2008).

The Psylloidea have not been subjected to extensive taxonomic or faunal analysis in Canada, except for work by Hodkinson (e.g., Hodkinson 1976) in British Columbia and Alberta. The identifiable forms of Coccoidea (adult female) and of Aleyrodidae (immatures) are sessile or subterranean and thus not captured by the usual general collecting methods. Consequently, the national fauna and regional distribution of species in these two groups are poorly known, and even limited efforts can yield new records. Kozár et al. (1989) identified several species of scale insects new to Canada based on brief collecting efforts in southern British Columbia. In a recent study of ant–sternorrhynch associations at a single grassland site in Alberta, two of the four species of Pseudococcidae found were newly recorded for Canada (Newton et al. 2011). The number of available BINs (see Table 1), largely based on untargeted sampling by the Biodiversity Institute of Ontario (University of Guelph), has indicated that current knowledge greatly under-represents the true fauna of Psyllidae and Aleyrodidae if BIN diversity can be considered a good approximation of species diversity in these groups.

Auchenorrhyncha

Worldwide there are about 43,024 species of Auchenorrhyncha (Bartlett et al. 2018), but an estimate for North America is currently not available. In Canada, Hamilton (1997, 2014) analysed the cicadellid fauna of the Yukon and the Canadian Prairie Ecozone, respectively, Gareau (2008) documented that of Quebec, and Wilson (1997) treated the Yukon Delphacidae. The taxonomic status of several auchenorrhynch groups has been updated. A number of papers by Hamilton (e.g., Hamilton 1983, 1994, 1998) have revised many groups of Cicadellidae. As well, the large and difficult tribe Erythroneurini has been completely revised by Dmitriev and Dietrich (2007, 2009, 2010). The

Table 1. Census of Hemiptera in Canada.

Taxon ¹	No. species reported in Scudder (1979) ²	No. species currently known from Canada ³	No. BINs ⁴ available for Canadian species	Est. no undescribed or unrecorded species in Canada	General distribution by ecozone ^{5A}	Information sources ⁵
Suborder Sternorrhyncha						
Superfamily Psylloidea						
Aphalaridae ⁶	50	37 (1)	19	10	all ecozones but Arctic	CNCI
Calophyidae ⁶	?	1	0	0	Mixedwood Plains	
Lividae ⁶	4	14 (3)	6	2	all ecozones but Arctic	
Psyllidae ⁶	35	52 (5)	65	20	all ecozones but Arctic	
Triozidae	18	25 (1)	13	10	all ecozones but Arctic	
Superfamily Aleyrodoidea						
Aleyrodidae	3	13 (4)	40	40	all ecozones south of taiga	CNCI
Infraorder Aphidomorpha						
Superfamily Adelgoidea						
Adelgidae	22	18 (5)	14	1	all ecozones but Arctic	
Superfamily Aphidoidea						
Aphididae	650	847 (164)	758	100	all ecozones	CNCI
Superfamily Phylloxeroidea						
Phylloxeridae	6	8 (2)	11	4	Pacific Maritime, Mixedwood Plains, Boreal Plains (1 sp.)	
Infraorder Coccoomorpha						
Superfamily Coccoidea						
Asterolecaniidae	1	2 (2)	0	0	Pacific Maritime, Mixedwood Plains	
Coccidae	15	26 (12)	7	5	all ecozones, mostly south of Arctic	
Cryptococcidae	?	2 (2)	0	0	Mixedwood Plains, Atlantic Maritime	
Dactylopiidae	1	1	0	0	Prairies	
Diaspididae	16	30 (10)	4	10	all ecozones, mostly south of taiga	
Eriococcidae	3	3 (2)	2	0	Pacific Maritime, Mixedwood Plains, Atlantic Maritime	
Kermesidae	0	4	0	1	Mixedwood Plains	
Margarodidae	4 ⁷	0	0	0	Mixedwood Plains, Atlantic Maritime	
Matsucoccidae ⁷	?	2	0	0	all ecozones but Arctic	
Orthozidae ⁸	3	5	2	0	all ecozones, mostly south of taiga	Newron et al. 2011;
Pseudococcidae	13 ⁹	25 (9)	11	10		CNCI

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Putoidea ⁹	?	2	0	0	Montane Cordillera, Boreal Cordillera	
Rhizoecidae	0	1	0	2	Pacific Maritime	CNCI
Steingeliidae ⁷	?	1 (1)	0	0	Mixedwood Plains	
Xyllococcidae ⁷	?	1	0	0	Atlantic Maritime	
Total Sternorrhyncha	844	1120 (223)	955	215		
Suborder Auchenorrhyncha						
Superfamily Fulgoroidea						
Acanaloniidae ¹⁰	?	2	2	0	Mixedwoods Plains	
Achilidae	17	19	15	3	all ecozones but Arctic	
Caliscelidae	7	11	7	0	mostly south of boreal	
Cixiidae	25 ¹¹	31	14	5	all ecozones but Arctic	
Delphacidae	81	138 (1)	102	30	all ecozones	
Derbidae	14	21	17	3	all ecozones south of taiga; most in Mixedwood Plains	
Dictyopharidae ¹²	4	8	5	1	widespread south of taiga	
Flatidae	1	3	3	0	Mixedwoods Plains	
Issidae	3 ¹⁰	2	1	0	Mixedwoods Plains	
Kinnaridae ¹¹	?	1	0	0	Western Interior Basin	
Infraorder Cicadomorpha						
Superfamily Cicadoidea						
Cicadidae	9	21	10	7	mostly south of taiga, Taiga Plains (1 sp.)	
Superfamily Cercopoidea						
Aphrophoridae ¹³	?	23 (4)	19	2	all ecozones but Arctic	
Cercopidae	33 ¹³	1	0	0	Mixedwoods Plains	
Clastropteridae ¹³	?	12	8	2	all ecozones south of taiga	
Superfamily Membracoidea						
Cicadellidae	800	1097 (76)	1144	150	all ecozones	Dmitriev 2018, specimens in CNCI
Membracidae	70	101 (1)	65	20	widespread south of boreal, few in Boreal Shield and Boreal Plains	Dmitriev 2018
Total Auchenorrhyncha	1064	1491 (82)	1412	223		

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Suborder [?] Heteroptera							
Infraorder Enicocephalomorpha							
Superfamily Enicocephaloidea							
Aenicopecheidae	0	1	0	0	Boreal Plains (single collection)	Scudder 2008 and references included therein, Scudder 2012, Roch 2017	
Enicocephalidae ¹⁴	1	1	2	1	Mixedwood Plains, Atlantic Maritime		
Infraorder Diposcoromorpha							
Superfamily Diposoroidea							
Ceratocombidae ¹⁵	1	1	7	5	Pacific Maritime, Mixedwood Plains		
Schizoprenidae	0	1 (1)	0	0	Pacific Maritime		
Infraorder Gerromorpha							
Superfamily Gerroidea							
Gerridae	19	22	13	1	all ecozones but Arctic		
Veliidae	6	8	6	0	all ecozones south of taiga		
Superfamily Hebroidea							
Hebridae	4	5	2	0	all ecozones south of taiga		
Superfamily Hydrometroidea							
Hydrometridae	1	1	1	0	Pacific Maritime, Prairies, Mixedwood Plains, Atlantic Maritime		
Superfamily Mesovelioidae							
Mesoveliidae	2	2	2	0	all ecozones south of taiga		
Infraorder Nepomorpha							
Superfamily Corixoidae							
Corixidae	72	79	57	2	all ecozones but Arctic		
Superfamily Naucoroidea							
Naucoridae	0	1	1	0	Mixedwood Plains		
Superfamily Nepoidea							
Belostomatidae	3	4	2	0	all ecozones but Arctic		
Nepidae	7	4	6	1	Mixedwood Plains, southern Boreal Shield		
Superfamily Notonectoidea							
Notonectidae	12	12	10	0	all ecozones but Arctic		

Taxon ¹	No. species reported in Scudder (1979) ²	No. species currently known from Canada ³	No. BINs ⁴ available for Canadian species	Est. no undescribed or unrecorded species in Canada	General distribution by ecozone ^{5A}	Information sources ⁵
Pleidae	2	1	1	0	Mixedwood Plains, southern Boreal Shield	
Superfamily Ochteroidea						
Gelastocoridae	1	1	1	0	Pacific Maritime, Prairies, Mixedwood Plains	
Ochteridae	0	1	0	0	Mixedwood Plains	
Infraorder Leptodomorpha						
Superfamily Saldoidea						
Saldidae	36	38	23	2	All ecozones, mostly south of Arctic	
Infraorder Cimicomorpha						
Cimicoidea						
Anthocoridae	41 ¹⁶	39 (7)	36	1	widespread south of taiga	
Cimicidae	4	7	3	0	widespread south of taiga	
Lastochilidae ¹⁶	?	1	0	0	Mixedwood Plains	
Lycotooridae ¹⁶	?	6	2	0	all ecozones south of taiga	
Superfamily Naboidae						
Nabidae	12	22 (3)	19	2	all ecozones south of Arctic	
Superfamily Microphysoidea						
Microphysidae	0	3 (3)	1	0	near Pacific and Atlantic ports of entry	
Superfamily Miroidea						
Miridae	60 ¹⁷	706 (57)	414	100	mostly south of Arctic, widespread	
Tingidae	46	52 (6)	30	10	all ecozones south of taiga	
Superfamily Reduvioidae						
Reduviidae	26 ¹⁸	29 (3)	20	0	all ecozones south of taiga	
Infraorder Pentatomomorpha						
Superfamily Aradoidea						
Aradidae	47 ¹⁹	51	13	2	all ecozones but Arctic	
Superfamily Coreoidea						
Alydidae	10	9	7	0	all ecozones but Arctic	
Coreidae	11	15	14	0	all ecozones but Arctic	
Rhopalidae	9	19 (1)	14	2	all ecozones but Arctic	
Superfamily Lygaeoidea						
Artheneidae	0	1 (1)	1	0	all ecozones south of taiga	
Berytidae ²⁰	3	5 (1)	6	0	all ecozones south of boreal	
Blissidae ²¹	?	6	4	0	all ecozones south of boreal	

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Cymidae ²¹	?	5	4	0	all ecozones south of taiga	
Geocoridae ²¹	?	10	5	0	all ecozones but Arctic	
Heterogastridae ²¹	?	2 (1)	0	0	Pacific Maritime	
Lygaeidae	100 ²¹	27 (1)	18	2	all ecozones, most south of Arctic	
Oxycarenidae ²¹	?	5 (1)	1	0	all ecozones but Arctic	
Pachygronthidae ²¹	?	3	4	1	all ecozones but Arctic	
Piesmatidae	1	4	1	0	all ecozones south of taiga	
Rhyparochromidae ²¹	?	71 (10)	52	7	all ecozones but Arctic	
Superfamily Pentatomoidae						
Acanthosomatidae	5	5 (1)	3	0	all ecozones but Arctic	
Cydidae	7	12 (1)	13	3	Pacific Maritime, Mixedwood Plains	
Pentatomidae	63 ²²	77 (1)	68	5	all ecozones but Arctic	
Scutelleridae	9	13	9	2	all ecozones but Arctic, mostly south of taiga	
Thyreocoridae ²³	9	11	12	2	all ecozones but Arctic, mostly south of taiga	
Total Hemiptera	1171	1400 (100)	908	151		
Total Hemiptera	3079	4011 (405)	3275	589		

¹Classification follows Ouvrard (2018, Psyllioidea), Favret (2018, Aphidomorpha), García Morales et al. (2016, Coccoidea), Bartlett et al. (2018, Auchenorrhyncha), and Henry (2017, Heteroptera). ²Some families not recognised by Scudder (1979) but which contain species included by him within other families, are indicate by ? in this column. ³Numbers in parentheses indicate the number of non-native species included in the total. ⁴Barcode Index Numbers, as defined by Ramasingham and Hebert (2013). ⁵See figure 1 in Langor (2019) for a map of ecozones. ⁶The baseline data for all groups is the most recent comprehensive checklist of Hemiptera in Canada (Maw et al. 2000). Sources given here are for subsequent additions to the known fauna. Collection abbreviation: CNCI, specimens in Canadian National Collection of Insects, Arachnids and Nematodes. ^{6A}As the delineation of families of Psyllioidea has changed since Scudder (1979), the number of species reported in 1979 for each family are not comparable to current totals with the exception of Trioziidae. ⁷In Scudder (1979), the count for Margaritidae included Matsucoccidae, Strengellidae, and Xylococcidae; no Canadian species remain in Margaritidae. ⁸Misspelled as Arthezidae in Scudder (1979). ⁹In Scudder (1979), the count for Psuedococcidae included Putoidea. ¹⁰In Scudder (1979), the count for Issidae included Acanaloniidae. ¹¹In Scudder (1979), the count for Cixiidae included Kinnaridae. ¹²Treated under Fulgoroidea in Scudder (1979); there are no Canadian species of Fulgoroidea s.str. ¹³In Scudder (1979), the count for Cercopidae included Aphrophoridae and Clastopteridae. ¹⁴Entocephalidae was listed under Reduviidae in Scudder (1979). ¹⁵Ceratocombidae was treated as part of Diposocoridae in Scudder (1979). ¹⁶In Scudder (1979), the count for Anthocoridae included Lasiochilidae and Lycotocoridae. ¹⁷Scudder (1979) reported on Miridae (600 spp.) and Isometopidae (1 spp.) separately; however, we have combined these counts for 1979 under Miridae. ¹⁸Scudder (1979) reported on Reduviidae (13 spp.), Phymatidae (3 spp.), and Ploariidae (10 spp.) separately; however, as these are all currently included in Reduviidae, we have combined the count for 1979. ¹⁹Scudder (1979) reported on Aradidae (46 spp.) and Merizidae (1 spp.) separately; however, we have combined these counts for 1979 under Aradidae. ²⁰Scudder (1979) reported this family as Berytidae. ²¹In Scudder (1979), the count for Lygaeidae included Arheneidae, Blissidae, Cymidae, Geocoridae, Heterogastridae, Oxycarenidae, Pachygronthidae, and Rhyparochromidae. ²²Scudder (1979) reported on Pentatomidae (61 spp.) and Podopidae (2 spp.) separately; however, we have combined these counts for 1979 under Pentatomidae. ²³Scudder (1979) reported this family as Corimelaenidae.

Cercopoidea were completely revised and a handbook published by Hamilton (1982). Progress on the Fulgoroidea includes a review of the North American fauna (Bartlett et al. 2014), which provides illustrated keys to all genera including the first comprehensive key to delphacid genera in the region. The known diversity of Canadian Auchenorrhyncha has increased since Scudder (1979), mostly as a result of taxonomic progress and improved knowledge of distributions. Currently, 1491 species are known from Canada compared to 1060 in 1979, and it is expected that a further 223 species will be eventually found in the country (Table 1). Most of the increases are in line with estimates of unrecorded species provided by Scudder (1979). The highest proportional increase is among the Cicadidae from nine to 21 recorded species; this increase is entirely due to improved knowledge of distribution (Hamilton 2010, Sanborn and Phillips 2013) as little taxonomic work has been done on the family in Canada. The highest numerical increase is among the Cicadellidae with an increase of 297 species; this is due to a combination of significant taxonomic research, greatly increased knowledge of distributions, and a small number of recently introduced species. We expect this family to hold the largest number of still unrecorded species (estimated at 150 species), particularly among the under-studied and under-collected subfamily Typhlocybinae.

Significant progress has been made in DNA barcoding of the Canadian Auchenorrhyncha. Data for 691 species have been released (Footitt et al. 2014, Gwiazdowski Heteroptodea et al. 2015) and unpublished data for additional species is available in Barcode of Life Data System (Ratnasingham and Hebert 2007). A simple comparison between the number of BINs and recorded species suggests that more than half the Canadian species have been barcoded in most families, and an impressive 91% of the highly diverse Cicadellidae. However, caution is required in interpreting these numbers. Single BINs have been shown to include multiple morphologically distinct species in a number of cicadellid genera (Footitt et al. 2014). Conversely, preliminary examination of BINs for the Typhlocybinae suggests that single species may be represented by multiple BINs. Thus, the number of BINs may not be predictive of the number of distinct species within these groups.

Heteroptera

There are about 45,254 described species of Heteroptera in the world. The most recent published comprehensive catalog for the group in North America (Henry and Froeschner 1985) includes 3834 species. About 1400 species are currently known to occur in Canada compared to 1171 in 1979, and it is expected that a further 151 species will be eventually added (Table 1). Most families of this suborder are relatively well known in the country. However, representatives of two families have been found in Canada only recently: Schizopteridae in 2010 (Scudder 2010a) and Aenictopecheidae in 2016 (Scudder and Štys 2016). Roch (2017) recently documented the Heteroptera of Quebec. Detailed analyses of the faunas of the Yukon, grasslands, Atlantic Maritime Ecozone and Montane Cordillera Ecozone have appeared (Scudder 1997, 2010b, 2011, 2014), and the aquatic and semiaquatic Heteroptera of Canadian peat-

lands and marshlands and the aquatic Heteroptera of the prairies and parklands were documented by Scudder (1987) and Scudder et al. (2010). Kelton (1980) provided a handbook of the Miridae of the Prairie Provinces. A major on-line database of the mirid fauna of North America (Schuh 2002–2013) includes records for a major portion of the holdings of the CNCI. DNA barcodes for the 334 species of Heteroptera drawn from CNCI (mainly Canadian species) were presented by Park et al. (2011) and reanalysed by Gwiazdowski et al. (2015).

The predicted number of Miridae constitutes the bulk of the estimate for Heteroptera overall, but this number is speculative and may be an underestimate if there are a significant number of undetected cryptic species within the more speciose genera.

Summary and opportunities

Despite the significant increase in knowledge of Hemiptera in Canada since 1979, a substantial amount of the country's biodiversity still awaits discovery. Some groups of Hemiptera are relatively well documented in Canada, while others are quite poorly known. However, even in the well-studied, but highly diverse phytophagous families (such as Aphididae and Miridae), there is probably unrecognised cryptic diversity associated with host plants and geographic variation. Several large genera in these families, such as *Lygus*, continue to present taxonomic difficulties (Schwartz and Footitt 1998) and opportunities for application of new approaches and technologies. Because many species of Hemiptera are current or potential pests, continuing research on detection, identification, quarantine and management of these groups will be required.

Acknowledgments

The express their thanks to Jeremy deWaard for updates to the number of available Barcode Index Numbers. We thank David Langor and Cory Sheffield for their critical comments.

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