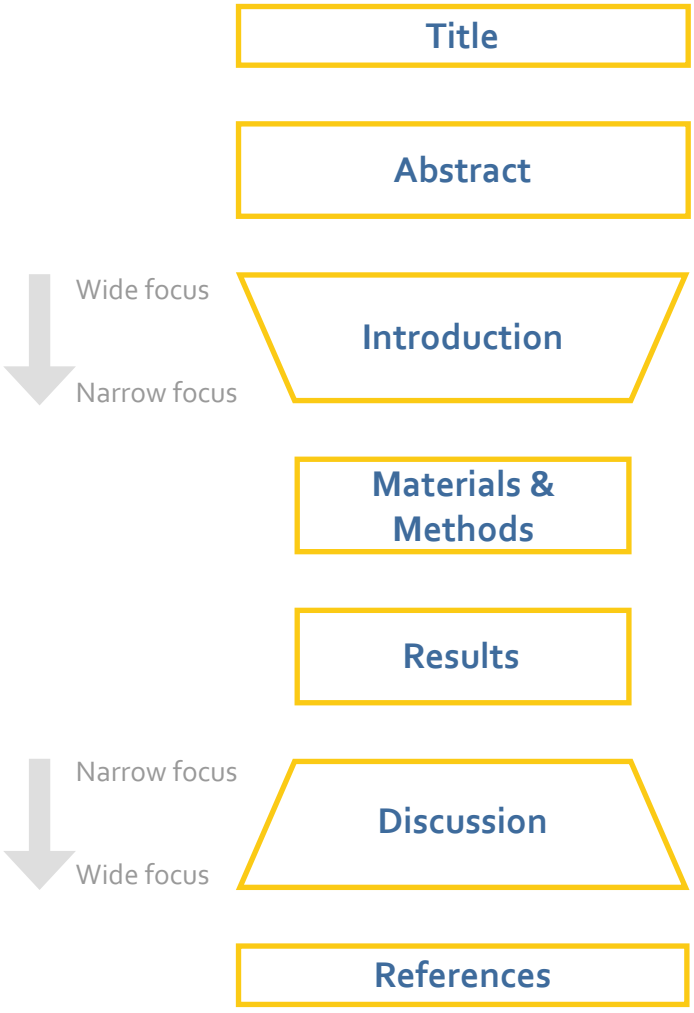
The Scientific Article

The scientific article is the genre frequently used to communicate the results of an investigation to a scientific audience. The structure of scientific articles will vary across disciplines; however, they generally follow the IMRAD format: Introduction, Materials & Methods, Results, and Discussion.
View each section for more information and examples.



Title
A concise and meaningful statement that summarises the outcome of your research.

Abstract
A summary of your article that includes information from the introduction, materials and methods, results, and discussion.

Introduction
A review of existing research and relevant background information.
What knowledge gap are you trying to fill?
What is your hypothesis or objective?

Materials and Methods
What did you do?
A comprehensive description, written in full sentences.

Results
What have you found?
Includes graphs, tables, and other figures.

Discussion
What do your results mean?
How do your results relate to existing research?
What questions remain unanswered?

References
A list of references that were cited in your article.

For more information on writing paragraphs, creating graphs, and referencing, browse the CLIPS website.

Introduction

An effective introduction will guide your audience through relevant background information, help them to understand the need for your research, give a brief overview of your experiment, and state the objectives or the hypothesis that was tested. By the end of the introduction, your audience should have a clear understanding of the topic and how your research will complement the existing body of knowledge.

Parts of the Introduction

Context/history
Provide some context or history that will help your audience to understand your research. The context should gradually become more specific until you reach the current situation.

The current situation
This section highlights recent research that is related to your study and provides more specific context.

The knowledge gap
This part should identify what is yet to be established in this area of research.

Your objectives/hypothesis
Your objectives or hypothesis should be clearly stated at the end of your introduction.

What you did
Provide your audience with a brief overview of what you did to fill the knowledge gap.

Think of your introduction as a funnel - broad, general information at the beginning and gradually narrowing to specific details of your investigation at the end.

Example

Cold bathing is a common custom in many parts of the world. Ever since the introduction of civilized bathing, humans have experimented with water temperature variation to expose the body to extreme conditions. In ancient times, Roman bathing was based around the practice of moving through a series of heated rooms culminating in a cold plunge at the end [1]. In modern times, the traditional ritual of the *frigidarium* has been kept in most saunas and spas around the world.

Cold bathing has been claimed to have multiple beneficial effects on health such as improvement of the immune system, cardiovascular circulation and vitality, but any true association remains unclear [2]. Previous investigations on the short-term effects of cold exposure have shown increases of cortisol and norepinephrine concentrations with modulation of the physiological response but showed minimal or no immune modulation [3–7]. However, the cumulative clinical effect and relevance for health after adaption of cold exposure (response conditioning) in healthy humans remain speculative as randomized controlled trials are lacking.

The primary objective of this trial was to determine whether perceived illness could be modulated after repeated pragmatic cold exposure by taking a cold shower for at least 30 consecutive days. Secondary objectives were to determine whether there was any effect on quality of life, work productivity and anxiety as well as adverse reactions.

A dose response relationship was investigated by varying in the duration of the cold shower.

nb. This example introduction is very concise. Most introductions provide much more background information.

Source: The Effect of Cold Showering on Health and Work: A Randomized Controlled Trial Buijze GA, et. al (2016) PLoS ONE 11(9): e0161749. doi: 10.1371/journal.pone.0161749

Materials and Methods

The materials and methods section provides your audience with details of how you performed your investigation. You should explain each of the steps you performed, ensuring you describe any specific chemicals, equipment, survey locations, and statistical methods. This section should enable another scientist to repeat the experiment, but it should also give some insight into the reasons why you performed the experiment in a certain way.

Logical/chronological order

You can structure your materials and methods section in chronological order, making it easy for your audience to follow. Most scientific articles will use sub-headings to divide the materials and methods into different parts. For example, you can use sub-headings to highlight separate experiments, study sites, procedures, and statistical analyses.

Full sentences, not dot points

The materials and methods section should be written as full sentences. This allows you to provide some justification for the methods, materials, or equipment that you have used. This section should be written in the past tense.

> "Sterile wet cotton swabs were streaked on leaves and citrus fruit surfaces and immediately placed into 10 mL of YEPD (yeast extract 5 g/L, peptone 5 g/L, dextrose 40 g/L, pH 4.5–5.0, 0.1 buffered mol/L phosphate citrate buffer) supplemented with 100 mg/L ampicillin and 50 mg/L chloramphenicol to inhibit bacterial growth."

Quantities, chemicals and equipment

The exact quantities of any chemicals or other materials must be included. Ensure that you use full names and abide by the international standards for measurements, and chemical and organism names. The name and details of any equipment you have used should be provided.

> "When separate seed fractions (cotyledons, embryos, and seed coats) were analyzed, the extraction solvent and the freeze-dried samples were reduced to 250 µL and 50 mg, respectively. Samples were crushed into a fine paste using a Fast Prep®FP120 (Qbiogene, Inc., Canada) with a maximum of seven consecutive times for 45 s each at a speed setting of 4.0."

Study sites

If you have performed any experiments or surveys in the field, you should provide the name and the GPS coordinates of the location, and provide a brief description of the site. The season, weather, and time of day are other details you may need to include for fieldwork.

> "We surveyed habitat characteristics and fauna at 16 campgrounds and picnic areas surrounded by bushland (from 28°220S, 153°140E to 29°570S, 153°150E) between October 2013 and February 2014."

Specific methods

If you have used a well-known protocol or specific method, you can mention this without having to explain the full procedure. Methods that involve DNA extraction and PCR generally just identify a specific brand, however any other methods you used to prepare or store samples should be provided.

> "Genomic DNA was extracted using QuickExtract DNA Extraction Solution (Epicentre Technologies Corporation) as per the manufacturer's instructions and was diluted 1:10 in purified water."

Statistical analysis

Provide the details of statistical tests and software packages that you used to analyse your data. Provide any necessary justification for the statistical tests that you used or specific methods for processing your data.

> "To test whether different species required different doses to achieve a similar decrement in swimming speed across all species, we performed an analysis of variance (ANOVA) with species as the factor and dose as the dependent variable."

Results

In this section you need to communicate the results of your investigation to your audience. You should describe the results of your investigation along with any statistics generated from the analysis of your data. Graphs and tables can be used to clearly display your results and improve audience understanding. After reading the results, your audience should know what you have found but gain no indication of the reasons for the results.

Logical/chronological order
It is important to present your results in a logical sequence to ensure you don't overwhelm your audience. Similar to the methods section, you can use sub-headings to break up the results into individual experiments.

What to include
Your audience is relying on you highlight the important data that you have gathered. Don't simply provide tables full of raw data and expect your audience to understand your results. Generally, you will perform an analysis on the data and only include the results to be discussed in your discussion section.

Writing about results
When writing about your results, you should provide clear, honest statements that illustrate the outcome of your investigation. The statements should be specific and include relevant data that are supported by statistics (when available).

> "All beetles belonged to one of four species, with *O. gazella* being the most abundant (3109 individuals, 93.2%); *E. intermedius* (130, 4.2%), *O. alexis* (41, 1.3%), and *O. viridulus* (40, 1.3%) occurred at low densities (Table 2)."

Communicating with statistics
Statistics can be used to add credibility to your results but you should ensure that you don't mislead your audience or leave them wanting more detail. Don't simply state that you found a significant relationship, you should state what relationship you found and support it with statistics. Results that are statistically significant will still require an interpretation in your discussion section to determine what they actually mean.

> "The number of cane toads per 100 m^2 was 6.4 times higher at dams (0.9 ± 0.25) than tanks (0.14 ± 0.03; GLMM, $F_{1,11} = 15.29$, $P < 0.01$; Figure 2A)."

Using tables
Tables can include large amounts of data that can display exact values from a range of categories or with varying units of measure. Tables allow an audience to look up and compare different groups or categories, but the relationships or trends will not be instantly recognisable.

Using graphs
Graphs are a visual representation of your data and can condense large amounts of information into a relatively simple image. Unlike tables, graphs should focus on one key message that your audience can understand quickly. Never include graphs and tables that display exactly the same data—choose the best format for the data.

For more details on displaying data, view the CLIPS Displaying Data module.

Referring to tables and figures
If you have created tables or figures from your data, you must refer to them in the text. The table or figure number should be placed in brackets at the end of a sentence that relates to the information in the table or figure (see previous examples). The table or figure should be placed immediately after the paragraph.

Reporting negative results
It is important that you include any results that were unexpected or did not support your hypothesis. These results can reveal relationships you may not have considered and can eventually lead to further research. In your discussion section, you can examine the reasons behind the negative results in further detail and compare them to the results of other research.

> "We also found no support for the metric range hypothesis. Extinction risk was not highest in species with intermediate mobility; instead, extinction risk increased with the emigration rate and decreased with the immigration rate."

Discussion

The discussion section should include explanations of what your results actually mean and how they contribute to existing research. The discussion generally takes the narrow focus of your investigation and expands into 'bigger picture' concepts that were mentioned in your introduction.

Interpreting your results

The first part of your discussion should focus on communicating the meaning of your results. Be careful not to simply restate your results. You should use your results to support specific arguments or explanations, discuss the possible reasons for your results, and analyse the associated mechanisms or processes.

> "Even though individual toads at dams consumed more dung beetles than toads at tanks (Figure 3A), their total impact on dung beetles was much greater because of the higher cane toad population densities at dams (Figure 3B)."

Do your results support your hypothesis?

Any hypothesis or objective that you included in your introduction should be referred to in your discussion. Even if your hypothesis was not supported by your results, you still need to discuss the relationship between your results and your hypothesis.

> "Our results provide support for the hypothesis that the low population densities of dung beetles observed at dams were due to high predation pressure by toads."

Referring to other research

Referencing existing research should be essential element of your discussion section. Following on from the background information you provided in your introduction, you should refer to similar or related investigations and discuss the reasons for any similarities or differences. You should consider other research as additional data that you can analyse and compare to your own results.

> "Earthen dams provide cane toads with virtually unlimited access to standing water for rehydration and hence can support large populations of toads (Florance and others 2011; Letnic and others 2014)."

Source: Invasive Cane Toads' Predatory Impact on Dung Beetles is Mediated by Reservoir Type at Artificial Water Points. Feit, B., Dempster, T., Gibb, H. et al. Ecosystems (2015) 18: 826. doi:10.1007/s10021-015-9865-x

The bigger picture

You should attempt to discuss your results as part of a bigger picture. How does your research contribute to the overall body of knowledge and why is it important?

> "Depletion of dung beetle populations by prolific cane toad populations at earthen dams could thus create a situation similar to that which existed prior to the introduction of dung beetles, when large areas of pasture were unavailable to livestock, cattle parasites had uncontrolled access to readily available dung to complete their life cycles and the release of nutrients from dung was slow (Bornemissza 1960)."

Limitations

You should be critical of your own methods and highlight any areas that could be improved. Keeping your results in mind, you should consider any factors that may have influenced the outcome of your investigation, such as small sample sizes, weather, or equipment limitations.

> "Although our results provide support for the hypothesis that predation by cane toads suppresses dung beetle abundance, we caution that without having conducted an experimental manipulation of cane toad abundance, causation remains difficult to attribute because it remains possible that confounding factors could have influenced our results."

Future research & conclusions

The final part of a discussion will often reiterate the findings of an investigation and explain how it has contributed to the existing body of knowledge. If your investigation has raised any questions, you can propose future research that may provide answers.

> "Our study furthers understanding of predators' effects on ecosystem processes because it provides evidence that consumption of detritivores by an introduced predator can retard the rate of herbivore dung decomposition and potentially hinder the functioning of rangeland ecosystems."

Abstract

The abstract provides your audience with a condensed version of your scientific article. Although the abstract is generally restricted to a single paragraph, it contains information from each of the distinct sections in a scientific article. Each section is usually summarised with 1-3 sentences. You should not include any excessive data and statistics, or references to tables or figures. The abstract is usually written once the other sections have been completed.

Parts of the Abstract

Example

This abstract has been broken up to highlight each section. The original version is only one paragraph.

Introduction Context	Private gardens provide habitat and resources for many birds living in human-dominated landscapes.
The knowledge gap	While wild bird feeding is recognised as one of the most popular forms of human-wildlife interaction, almost nothing is known about the use of bird baths.
Your objectives	This citizen science initiative explores avian assemblages at bird baths in private gardens in south-eastern Australia and how this differs with respect to levels of urbanisation and bioregion.
Materials and Methods What you did	Overall, 992 citizen scientists collected data over two, four-week survey periods during winter 2014 and summer 2015 (43% participated in both years).
Results What you found	Avian assemblages at urban and rural bird baths differed between bioregions with aggressive nectar-eating species influenced the avian assemblages visiting urban bird baths in South Eastern Queensland, NSW North Coast and Sydney Basin while introduced birds contributed to differences in South Western Slopes, Southern Volcanic Plains and Victorian Midlands. Small honeyeaters and other small native birds occurred less often at urban bird baths compared to rural bird baths.
Discussion What your results mean	Our results suggest that differences between urban versus rural areas, as well as bioregion, significantly influence the composition of avian assemblages visiting bird baths in private gardens.
Future perspectives	We also demonstrate that citizen science monitoring of fixed survey sites such as bird baths is a useful tool in understanding large-scale patterns in avian assemblages which requires a vast amount of data to be collected across broad areas.

Source: Avian Assemblages at Bird Baths: A Comparison of Urban and Rural Bird Baths in Australia
Cleary GP, Parsons H, Davis A, Coleman BR, Jones DN, et al. (2016) PLoS ONE 11(3): e0150899.

Structured Abstract

Similar to a standard abstract, a structured abstract provides your audience with a condensed version of your scientific article. However, a structured abstract will include headings for each section and the results section will often include more data and statistics than a standard abstract. Structured abstracts are common in medical research that focuses on clinical trials or case studies. As with a standard abstract, the structured abstract is usually written once the other sections have been completed.

Parts of the Abstract

Example

Headings for structured abstracts will vary between journals.

Introduction
Context
The knowledge gap
Your objectives

Background: In recent years, there has been growing awareness of the significant burden of Chagas disease in the United States (US). However, epidemiological data on both prevalence and access to care for this disease are limited. The objective of this study is to provide an updated national estimate of Chagas disease prevalence, the first state-level estimates of cases of *T. cruzi* infection in the US and to analyze these estimates in the context of data on confirmed cases of infection in the US blood supply.

Methods
What you did

Methods: In this study, we calculated estimates of the state and national prevalence of Chagas disease. The number of residents originally from Chagas disease endemic countries were computed using data on Foreign-Born Hispanic populations from the American Community Survey, along with recent prevalence estimates for Chagas disease in Latin America from the World Health Organization that were published in 2006 and updated in 2015. We then describe the distribution of estimated cases in each state in relation to the number of infections identified in the donated blood supply per data from the AABB (formerly American Association of Blood Banks).

Findings/results
What you found

Findings: The results of this analysis offer an updated national estimate of 238,091 cases of *T. cruzi* infection in the United States as of 2012, using the same method as was used by Bern and Montgomery to estimate cases in 2005. This estimate indicates that there are 62,070 cases less than the most recent prior estimate, though it does not include undocumented immigrants who may account for as many as 109,000 additional cases. The state level results show that four states (California, Texas, Florida and New York) have over 10,000 cases and an additional seven states have over 5,000 cases. Moreover, since 2007, the AABB has reported 1,908 confirmed cases of *T. cruzi* infection identified through screening of blood donations.

Conclusions
What your results mean

Future perspectives

Conclusions: This study demonstrates a substantial burden of Chagas disease in the US, with state variation that reflects the distribution of at risk Latin American immigrant populations. The study lends important new insight into the distribution of this disease in the US and highlights the need for further research quantifying prevalence and incidence to guide interventions for control of Chagas disease across the US.

Source: Estimating the Burden of Chagas Disease in the United States
Manne-Goehler J, Umeh CA, Montgomery SP, Wirtz VJ (2016). PLoS Negl Trop Dis 10(11): e0005033.

Abstract - version 2

The abstract provides your audience with a condensed version of your scientific article. Although the abstract is generally restricted to a single paragraph, it contains information from each of the distinct sections in a scientific article. Each section is usually summarised with 1-3 sentences. You should not include any excessive data and statistics, or references to tables or figures. The abstract is usually written once the other sections have been completed.

Parts of the Abstract

Example

This abstract has been broken up to highlight each section. The original version is only one paragraph.

Introduction
Context

Disruption to ecosystem functioning associated with biological invasions can have dramatic effects on the production and biodiversity values of ecosystems. In semi-arid rangelands of Australia, invasive cane toads (*Rhinella marina*) prey on dung beetles that were themselves introduced to promote nutrient cycling and reduce parasite burdens of livestock. Cane toads' colonization of rangelands has been facilitated by artificial water points (AWP) which provide cattle with drinking water. Most AWP in northern Australia comprise bores that pump water into earthen reservoirs (dams). Dams typically support large toad populations because they allow toads' access to water without which they could not survive.

The knowledge gap
Your objectives

Here, we ask if restricting toads' access to water at AWP can reduce toad populations, toads' predatory impact on dung beetles, and the rate of dung decomposition by dung beetles.

Materials and Methods
What you did

We contrasted toad and dung beetle populations, toad diets, and dung removal rates at AWP fitted with dams or tanks as reservoirs.

Results
What you found

In comparison to dams, tanks provide toads with little access to water. Population densities of toads were five times higher at dams than tanks. Conversely, population densities of dung beetles were 12 times lower at dams than tanks. Mass loss of experimental dung pats after 2 days was 13% greater at tanks than dams.

Discussion
What your results mean

Our study provides evidence that consumption of detritivores by an introduced predator can retard dung decomposition in a rangeland ecosystem.

Future perspectives

Restricting toads' access to water at AWP should benefit livestock production by reducing both toad populations and toads' predatory impact on dung beetles.

Source: Invasive Cane Toads' Predatory Impact on Dung Beetles is Mediated by Reservoir Type at Artificial Water Points. Feit, B., Dempster, T., Gibb, H. et al. Ecosystems (2015) 18: 826.