INTRODUCTION

SAFETY DISCUSSION

1-BEGINS WHEN YOU GET OUT OF BED.
2-MEDICATION
3-HOT COFFEE
4-WALKING OUT THE DOOR DOWN THE STEPS.
5-BACKING OUT OF THE DRIVE WAY.
6-TRAVELING DOWN THE STREET
AND YOU HAVE NOT EVEN MADE IT TO WORK

OPEN DISCUSSION THEN

A. **SAFETY POLICY**
B. **OCCUPATIONAL SAFETY AND HEALTH**
C. **HOUSEKEEPING**
D. **ITEMS TO DISCUSS IN TOOL BOX SAFETY**
E. **EYE INJURIES**
F. **EMERGENCY EVACUATION PROCEDURE AND PRACTICE**
G. **HOW ACCIDENTS ARE CAUSED AND HOW TO INVESTIGATE THEM**
H. **NEAR MISS/HIT REPORTING**
I. **TOOL BOX MEETINGS**
J. **FIRE PREVENTION**
K. **BACTERIAL HAZARDS**

QUESTIONS

NEXT TOPIC FOR MEETING

Buzzle

Workplace Safety

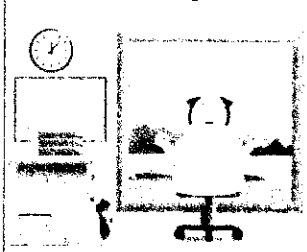
A happy and secure employee generates better output is a known fact. Take good care of your employees by incorporating workplace safety management in your organization. Encourage and motivate your workforce to perform better with passion and zeal.

Quotes About Workplace Safety

Safety in the workplace is the joint responsibility of the entire workforce of an organization. Safety quotes for the workplace can be quite an effective way of spreading the message about office and workplace safety. You can use...

Office Safety Tips - Safety in the Workplace

Keep your workplace clean and attain inner peace!

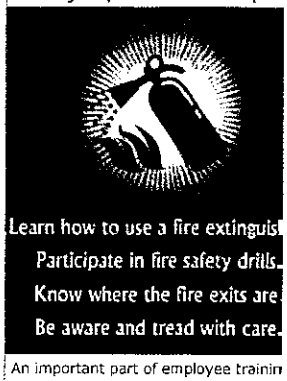


Worried about the safety in the workplace? Looking for an article on safety tips? Here are some office safety tips that will be helpful to you.

Safety Messages for Work

There isn't a company or job that doesn't have its own set of hazards. These hazards make it very important for an employer to put up safety messages in his office or workplace. Let's have a look at several such safety messages and...

Safety Topics in the Workpla

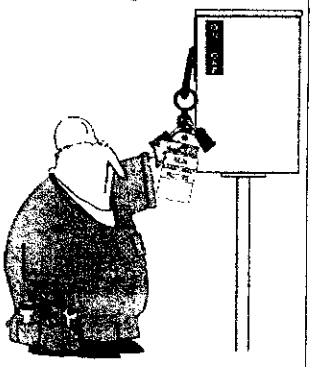


An important part of employee trainin to get them acquainted with all the ba safety measures. Here's an article on some safety topics that should be discussed at work. Some of the subje are field specific of course, but...

Why is Safety Important at the Workplace?

What is workplace safety? Why is safety at work important? To know why, you must read on.

Lockout Tagout Procedures

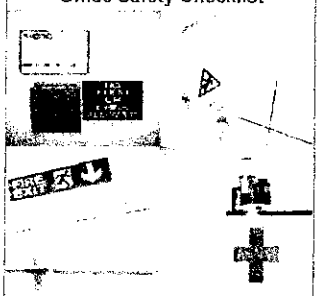


Lockout and tagout procedures are followed in order to ensure the safety of employees at the workplace. These procedures mainly aim to prevent the mishaps taking place on account of accidental activation of equipment resulting in...

Workplace Safety Slogans

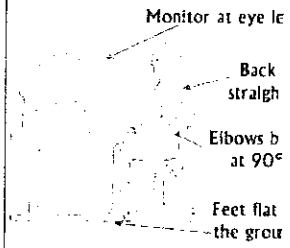
Promoting safety is an efficient way to keep up an employee's awareness against safety. In fact, many corporates make use of safety slogans or quotes that encourage and ensure safety, which is an effective tool of communication....

Office Safety Checklist



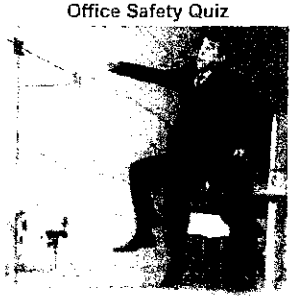
Does your office have a safety checklist? If not, go through the one in this article, and get one ready for your office, pronto!

Workplace Safety Tips



Accidents occur unannounced. Be it a home or at the workplace, it is very important to be prepared for such mishaps. Here are some workplace safety tips that should be followed to ensure well-being of employees at the workplace...

Office Safety Quiz



Does your office have a regular, mandatory office safety quiz? Are you searching for questions to address in the quiz? If you require a fresh quiz or need

Workplace Safety Training

Any workplace may it be a factory, office, a construction site, farm and dairy or for that matter any location place of work, is basically a second home to employees. Ensuring the safety of employees in such places, in every...

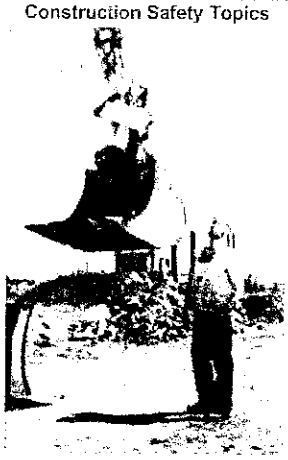
Eye Safety at Work

Office Safety Meeting Ideas

In order to make employees understand the importance of office safety, it becomes the responsibility of the management to make sure that the meetings that they hold for the purpose are sufficiently interesting, so that the...

Workplace Health and Safety Tips

Construction Safety Topics



Safety during construction is not to be taken lightly by organizations and its employees. Which is why, discussing over various construction safety topics becomes highly essential before work

to update the existing quiz, read the article for information...

Workplace Safety Checklist

A workplace safety checklist helps the housekeeping staff to maintain the safety decorum and avert any dangerous situations. Here are some safety guidelines that will help you chalk out your own list.

What is Lockout/Tagout?

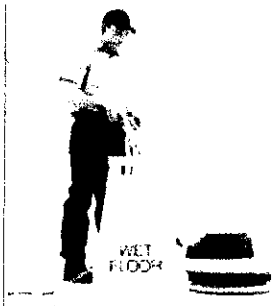
There are various safety measures that an organization should implement to ensure that its workers are not put to any risk of injury. Lockout/Tagout is one such procedure that is used in organizations dealing with heavy machinery...

Sweatshops: No Longer a Thing of the Past

A century ago, American workers and politicians made great strides in eliminating sweatshops in filthy factories in big cities throughout America. But recently, sweatshops have been making an unfortunate comeback.

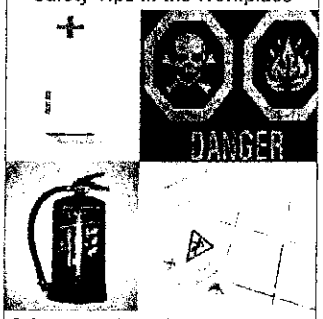
Workplace Health and Safety Messages

Eye injuries while working, have affected the lives of many on-site workers



Workplace health and safety messages play a very important role in preventing accidents or small mishaps in the office. This article gives you some useful safety messages for work...

Safety Tips in the Workplace



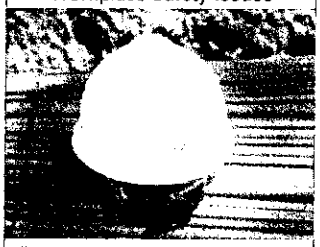
Safety tips in the workplace are a necessity these days. Read some in this article, and incorporate them in your office ASAP!

Along Related Lines

- **Safety Meetings** [15]
- **Safety** [21]
- **Occupational Health** [12]
- **Electrical Safety** [13]
- **Safety Officers** [5]

It is a fact that safety is the most important thing in any environment, be it at home or at work. If you are looking for some health and safety tips for your workplace, then you must continue reading to know the essentials.

Workplace Safety Issues



All organizations and companies have a huge responsibility of workplace safety for their employees. But there are a few issues, usually observed in all workplaces. These are mentioned in the coming up article, read on.

Safety Regulations in the Workplace

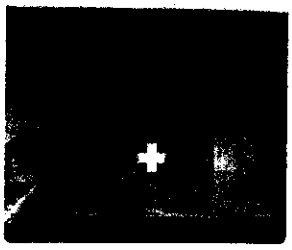
Safety regulations in the workplace need to be in place in order to assure the employees that they are cared for. Read this article for information on safety rules that apply for every workplace.

Industrial Safety Training

The idea behind industrial safety training is to gear the work force to understand their roles and responsibilities within the company and develop and apply work place safety measures.

commences. In the following article, we...

Why is Health and Safety Important in the Workplace

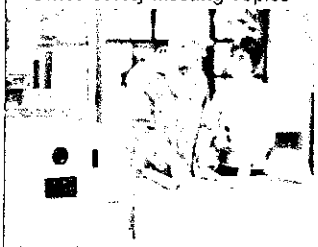


Understanding the importance of safety and health in a workplace is important for employees as well as for employers. We have provided you the most obvious reasons on why they are important. Read on...

Creating a Safe Work Environment

Organizations which care for their employees by providing them with safe working conditions, reap the benefits by way of increased productivity and profits. Scroll down to know the various measures that organizations should take to...

Office Safety Meeting Topics



This article shares some insights on safety meeting topics that will help you come up with some relevant topics for safety meetings.

Workplace Safety Facts

Safety at the workplace should be given its due importance. It involves safeguarding health and well-being of the employees by protecting them from the threat of injury or death when working. Here we take a look at some important...

You May Like

- **Business Security** [4]
- **Workplace Communication** [58]
- **Workplace Ethics** [65]
- **Internet Safety** [16]
- **Fire Safety** [11]

Buzzle

Safety Tips in the Workplace

Safety tips in the workplace are a necessity these days. Read some in this article, and incorporate them in your office ASAP!

One of the major causes of concern these days, is fast becoming workplace safety. How much the management does for the well-being, safety and security of its employees, should be clearly seen and understood. There are a lot of safety topics in the workplace, that need to be discussed very seriously with the management and the employees. As the old adage goes, better safe than sorry. So why not decide that today is going to be the day when you take the matter of safety topics up with the management or the employees, and ensure that they are all well versed with some valuable safety tips that will help them in the workplace. This Buzzle article will help you with some office safety tips that you can pay attention to.

Being Safe in your Workplace

There are a lot of workplace safety topics that need to be discussed. And these need to be discussed not only at the management level, and just thrust upon the employees. But they need to involve the employees as well, in the decision-making process. Let's see some workplace safety tips that you can use to make your office a safer place.

Meet Up

For deciding on any office safety topics, the first step that needs to be taken is to hold safety meetings in your workplace. Use these meetings to discuss with each other and with the management, any matters of concern that you have, regarding your personal safety and security. These topics could be related to health, hygiene, disaster planning, occupational hazards and injuries, ergonomics, and even crime. Do not be afraid or embarrassed to discuss any such topics. It is after all, a matter of your life.

Decide and Train

Once you have had your meetings, you can reach some decisions about the topics mentioned above. These decisions have to be made only with the consent of the majority, as they have to be in the interest of the people working. Once decisions have been made, use them to teach and train the employees about the various measure they can take to ensure and enhance office safety. Have mock fire drills, to see if the provisions made for a fire escape are sufficient or not. Give the employees pass-codes to enter and exit the building, and also for their individual systems, to ensure the safeguarding of company information. Use such methods to make the employees feel more cared for and secure.

Communicate

Make it a point to keep workplace safety at the top of every employee's mind. For this, you can have

different quotes about workplace safety scribbled on posters or kept as screen savers. You can also have them printed on t-shirts, mugs, stationery, company literature, as email signatures, stickers in washrooms, button-pins, fliers, etc. Choose a theme revolving around office safety and follow it for an entire month. This way, it will remain fresh in their minds.

Check

One of the most important things that you can undertake as safety precautions in the workplace, is to have a comprehensive office safety checklist prepared. This checklist should include every small and big item, that may cause any kind of problem, injury, health hazard, or compromise the hygiene or any other aspect of the time that is spent within the office. Have a checklist printed out for each department, and paste it in their respective departments. In addition to this, hand out versions to all employees, and also the staff that is responsible for the housekeeping and maintenance of the office premises. Have routine audits to check if these checklists are indeed being followed, or are they being ignored. Another purpose this serves is, that once you give your employees this checklist, and if they ignore it, they cannot blame or charge you for a mistake that they commit.

Quick Tips

- Keep all floors dry at all times.
- Keep the fire safety equipment in working condition.
- Label doors which lead to sensitive areas clearly.
- Provide helmets to people entering a construction site.
- Refrain from keeping sharp objects lying around.
- Turn off all electrical switches when not in use.
- Do not use escalators or elevators in case of a fire.
- Keep emergency numbers close at hand on every desk.
- Do not permit people to enter sensitive areas without appropriate protection.

Those were some useful workplace safety tips that you might want to incorporate in the next safety meeting that you have at office. Follow them, stay safe and help others to too!

By Sujata Iyer
Last Updated: 9/3/2011

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Free Safety Policy

Having a safety policy is often the first step taken towards organising and documenting your safety management system. What you actually put in your policy is up to you but if you follow the guidelines provided by national standards you won't go far wrong.

You should include commitments to: provide a safe and healthy workplace; comply with relevant occupational safety and health legislation; identify, assess and control hazards; provide information, instruction, training and supervision so employees can work safely; consult with employees on safety issues and to set measurable safety and health objectives as a minimum.

Add some statements about safety also being the responsibility of each employee and that the company seeks to continually improve safety in the workplace. The point is your policy doesn't have to be complicated - in fact the simpler the better.

Here's an example (based on ANSI Z10, BS 8800, OHSAS 18001, AS 4801, ILO requirements) that you can adapt to your own requirements:

Safety and Health Policy

(Insert company name) is committed to providing a safe, healthy and accident free workplace for all its employees, contractors and visitors by complying with relevant occupational safety and health legislation.

(Insert company name) shall:

- identify hazards, assess risks and implement appropriate controls
- provide employees, contractors and visitors with information, instruction, training and supervision appropriate to the hazards they are likely to encounter
- deal with safety and health matters in consultation with employees
- set measurable safety and health objectives and targets.

Each employee is personally responsible and accountable for their safety and health performance and this shall be reviewed regularly.

(Insert company name) shall provide the time and resources necessary to implement this policy and shall develop, implement and review its objectives, targets, plans and procedures to continually improve workplace safety and health.

To achieve a high standard of safety and health involves shared responsibilities and teamwork. Consequently, (insert company name) is committed to a consultative approach in which all employees at all levels of the organisation are responsible for their own and other people's safety and health in the workplace.

Signed: Chief Executive Officer Date: _____

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Occupational safety and health

From Wikipedia, the free encyclopedia
(Redirected from Industrial safety)

Occupational safety and health is an area concerned with protecting the safety, health and welfare of people engaged in work or employment. The goals of occupational safety and health programs include to foster a safe and healthy work environment.[1] OSH may also protect co-workers, family members, employers, customers, and many others who might be affected by the workplace environment.

Occupational safety and health can be important for moral, legal, and financial reasons. All organisations have a duty of care to ensure that employees and any other person who may be affected by the companies undertaking remain safe at all times.[2] Moral obligations would involve the protection of employee's lives and health. Legal reasons for OSH practices relate to the preventative, punitive and compensatory effects of laws that protect worker's safety and health. OSH can also reduce employee injury and illness related costs, including medical care, sick leave and disability benefit costs. OSH may involve interactions among many subject areas, including occupational medicine, occupational hygiene, public health, safety engineering, industrial engineering, chemistry, health physics, industrial and organizational psychology, ergonomics and occupational health psychology.

Contents

- 1 Definition
- 2 Workplace hazards
  - 2.1 Physical and mechanical hazards
  - 2.2 Biological and chemical hazards
    - 2.2.1 Biological hazards
    - 2.2.2 Chemical hazards
  - 2.3 Psychological and social issues
- 3 Occupational safety and health by industry
  - 3.1 Construction
  - 3.2 Agriculture
  - 3.3 Service sector
  - 3.4 Mining and oil & gas extraction
- 4 Workplace fatalities statistics
  - 4.1 European Union
  - 4.2 United States
- 5 History
- 6 Management systems
  - 6.1 International
  - 6.2 United Kingdom
- 7 National legislation and public organizations
  - 7.1 European Union
  - 7.2 United Kingdom
  - 7.3 Denmark
  - 7.4 United States
  - 7.5 Canada
  - 7.6 Malaysia

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Housekeeping - Show You Mean Business

First impressions do count and so does a clean, tidy, well laid out workplace. So when starting to get to grips with safety it's important to demonstrate clearly that something has visibly changed in the organisation - physically changed, it's clean, tidy and well organised.

To make it look different we suggest that the whole place is given a good clean up, the junk is removed, work areas are re-organised because of the extra space available, gear is stored properly, yellow lines are marked on the floor to indicate areas to be kept clear and all the appropriate safety signs are erected.

The clean up and general presentation of your site should also extend to the front of the building, any parking areas or gardens, as well as to the side and rear, including lay-down areas and the perimeter.

Work on the basis that first impressions of the front and internal areas of the building may be taken as a reflection of the attitude and ability of the firm, its CEO and the senior managers - neat, efficient and well organised - Great. Dirty, scruffy and disorganised ..... Well, your visitors will draw their own conclusions about the standard of leadership and the quality of work.

So, the first step is simple - **Clean Up and Throw Out**. Many workplaces are cluttered with accumulated scrap, old broken equipment, rubbish, old pallets, old drums, tyres, empty or half used containers of something, broken machinery (I've seen whole rooms dedicated to the storage of broken chairs, furniture, carpet and old computers.)

As you know, there is always a good reason for keeping junk - "Well, you never know when we'll need it, " or, "we keep it just in case," or, "we may need it for spare parts." There are a hundred reasons. But, **if in Doubt, Throw it Out**.

The point is that all the dead, unproductive space the junk is taking up is costing you money. Your people are having to work around it all, it's difficult to find equipment or get at it, and they're complaining there is not enough space.

Once you have got rid of all the junk, the problem now is to keep everything up to scratch. One of the best ways to do this is to carry out regular (at least monthly) housekeeping inspections using a form set up like the one below. Obviously, you will have to add on a few more items to cover all work areas.

The form below is written in such a way that everyone knows exactly what they are looking for - they don't have to guess. When you develop your own form write the inspection items in the same way and state clearly the standard you want.

Location:		**Date of Inspection:**	
Name/s of Person/s Inspecting:			

Topic	**OK**	**Not OK**	**Corrective Action**		
			Action Required	**By Whom (name)**	**By When (date)**
Fire Extinguishers in place, sign above & serviced within last six months					
Exit doors open easily from inside					
Exits clear of obstructions					
Emergency procedures displayed					
Electrical No broken plugs, sockets or switches					
No frayed or damaged leads					
Portable power-tools in good condition					
No temporary leads on floor					
No strained leads					
etc, etc, etc.					

And who should do the inspections? Well, initially I would expect supervisors and safety committee people to do them. After that, I recommend that you train everyone to carry out an inspection of their area. As long as your checklist makes it clear what is required, getting shopfloor employees involved in inspections will often identify things which you have overlooked. Also, it will give your employees the opportunity to get involved in safety and make their own contribution.

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Here you will find a collection of **free occupational safety and health solutions** to problems, tips, topics, issues, hints, shortcuts, ideas, solutions, guidelines and articles to review and use **within your own organisation and at safety committee meetings**.

Tool Box Meetings for Team Building and Commitment
Emergency Evacuation Procedures and Practice
Safety Management Systems - Why You Need One
Due Diligence - Directors & Executive Managers - Are You Doing Enough?
Free Safety Policy
Enforcing the Rules - Your Responsibility
Back Belts - Do they Work? Are they Worth it?
Safety Committee Meetings - Get Them Working for You
Housekeeping - Show You Mean Business
Eye Injuries - The Easiest Injury to Prevent
Near Miss / Hit Reporting - Your Early Warning System
Setting Safety Standards with an Employee Safety Handbook
How Accidents are Caused and How to Investigate Them
Fire Warning - Clean up Now
Fire Prevention
Office Parties and Safety

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Eye Injuries - The Easiest Injury to Prevent

Eye injuries are one of the most common injuries that occur in the workplace but luckily they are one of the easiest to prevent.

Many of you will say that even though your people are required to wear eye protection, injuries are still taking place. If this is the case there will usually be two reasons for this.

Firstly, even though you provide eye protection and have eye safety rules in place it is possible that the rules are not being followed, or, more to the point, they're not being enforced by your supervisors and managers (and perhaps you). Like all safety rules, they are there to be complied with, not sometimes, but every time. So, enforce the rules and procedures.

The second reason why eye injuries are occurring will be probably because the eye protection provided is not suitable for the hazards your workers face.

There is a common misconception that safety glasses are suitable for preventing all types of eye injury hazards - they are not. Safety glasses are only designed and suitable for preventing eye injuries where a particle or particles likely to cause injury are forcibly projected at the worker and the particle is travelling at a right angle to the plane of the safety glasses lens i.e. the particle is travelling directly and forcibly at the eye ball.

Safety glasses are totally inadequate protection for preventing eye injuries when using a grinding wheel, rotating wire brush, linisher, angle grinder, when hammering metal on metal, using metal wedges, cold chisels, chipping welds etc.

Many eye injuries occur to people wearing safety glasses when using a grinding wheel or rotating wire brush because the grit or broken pieces of wire fly off at great speed and hit the worker's face, cheek bones and forehead and the particle is deflected under the safety glasses and into the eye.

If your people are using grinding wheels, angle grinders, rotating wire brushes or hammering metal on metal they must wear either goggles or a full face shield or, possibly, safety glasses and a face shield. With this gear being used the chances of having an eye injury is reduced to about zero. But the correct gear must be worn every time without exception.

Safety glasses are obviously inadequate for preventing chemical or liquid splash injuries. Use a chemical full face shield (it's sealed at the top to prevent liquid running down into the eyes) or chemical goggles. For dusty conditions goggles are the only solution.

Bottom Line: Safety glasses are not the solution to the prevention of all eye injuries. Choose the correct eye protection for the different eye hazards to which your employees are exposed.

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Emergency Evacuation Procedures and Practice

Have you ever been involved in an emergency evacuation practice or drill that dissolved into chaos and confusion? It seems that many organisations are totally preoccupied with speed - how fast can we get them out? This is OK if you have practiced evacuating many times but if not what you should be concentrating on is **getting it right and not trying to beat a speed record**.

So let's get it right from the start - to put it simply, the purpose of any evacuation procedures is to: **Move People from Danger to Safety**.

So first of all you need a procedure for getting people away from danger. You may have other procedures for shutting down machinery, fire fighting etc - but what we are talking about here is getting the people out - this is the first and most important objective.

Procedures: These should be short and simple; at a minimum they should cover Fire, Earthquake, Bomb Threat and Medical Emergency situations. You can add in Hurricane, Cyclone, Typhoon and Storm Surge information if this is appropriate. The procedure for each emergency situation should be written in point form (use large print) with a maximum of about six points for each situation. Use one sheet of paper for each emergency situation. If your evacuation procedures are any longer than this you run the risk of confusing people.

The Alarm: It must be possible to hear the emergency alarm at all places on your site. I recommend that you install a two tone alarm which you feed through your intercom system or through well located sirens. With the two tone system, the first alarm you put out is The Alert (beep, beep, beep) - this tells everyone that something is up. If you then want to evacuate, you switch to the Evacuate tone (whoop, whoop, whoop) to get things moving. Having a two tone system gives you more control over what is happening.

Evacuation Practice: Many organisations seem to like to spring practice evacuations on employees without warning and then time them to see how long it takes to get out. This is OK if you have practised your evacuation procedures many times before and everyone knows what to do, but if you only practice your procedures once a year it is totally pointless trying to catch people out - because you will and the practise will be a waste of time.

The purpose of the initial practices is to get everyone familiar with the **correct** way of doing things - therefore:

- give plenty of warning of exactly when the practice will be

- brief all the wardens and deputy wardens immediately before the practice telling or reminding them what they are required to do. (Don't forget to cover how to get the people back to work when the practice is over.)
- stress that speed is not important at this stage - what is important is that everyone gets the process of evacuation right - speed can be developed later, and of course, walk, don't run

So by this stage everyone should know what is going to happen, when it will happen and what to do. Great, now you can sound the Evacuate signal and see what happens.

After the practice hold a short de-briefing session with all the wardens and deputy wardens to find out what worked, didn't work or can be improved. Based on this feedback you may find that you may have to make a few adjustments. Then set the date for the next practice. Keep on practising to get it right; when you are happy with everyone's performance, then you should consider doing a practice without warning.

Bottom Line: Don't try to catch them out - the idea is to get everyone doing it properly. Throw away the stop watch - speed is not important at the beginning. Yes, everyone should be involved in the evacuation practice, even those very important senior people who always seem to have something very important to do when everyone else is evacuating - aren't senior managers there to set the example?

For further information on this topic see Emergency Evacuation Procedures

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How Accidents are Caused and How to Investigate Them

Invariably accidents are caused by a number of shortcomings, failures, oversights, omissions, didn't do's, should have done's etc etc.

In every accident I have investigated there has been no single cause - there is always a number of causes or contributing factors, each interacting with the others in a complex way.

Most accidents are caused by a combination of poor communication, poor leadership, poor or inadequate training, tiredness, boredom, no procedures, failure to follow procedures, lack of experience, poor design, inadequate maintenance, lack of time and money, work pressure, the corporate culture ..... and the list goes on and on.

When you look at the contributing factors above it will be seen that most of them are the result of poor management (there are, I grant you, a few exceptions.)

The secret of effective and useful accident investigation is to **establish the Root Causes of the accident** in question (Root Cause Analysis).

And how to do Root Cause Analysis - easy, just ask "Why?" and keep on asking, "Why?"

"Why did he trip over the box?"

"Because ....." "Why?"

"Because ....." "Why?"

"Because ....." "Why?"

and keep on asking Why? (but not normally more than four or five times) until you can't ask it again - by this time you should have probably got a good idea of what one or more of the **root causes** are. Then repeat the process, "Why was the box there?" "Because ....." Why?" Because ....."Why?"

Those of you who are familiar with Cause and Effect or Fishbone diagrams can use this Total Quality Management (TQM) technique to establish root causes because, essentially, it uses a very similar process. Sure, we can make Root Cause Analysis a lot more fancy if you want, but just using the above processes is a massive leap forward in understanding how and why accidents happen.

Accident prevention is all about systems which work, procedures which are prepared, understood and used. It's about leadership, motivation, of having the will to fix the root causes of accidents rather than embroidering round the edges.

In many organisations the same type of accidents happen over and over again to the point where they are predictable. When this happens it is usually a clear indication that the root causes of these accidents have not been fixed - and if they are not fixed the accidents will continue to reoccur.

And the point is that management has all the tools necessary to fix these problems of accident prevention and reoccurrence - it is just how to use the tools so you get **Productivity with Safety** that many people find confusing.

Bottom line:

- accidents always have a number of Causes
- keep asking, "WHY?" and/or
- use Cause and Effect or Fishbone diagrams to establish Root Causes
- fix root causes *permanently* to prevent accident reoccurrence
- management already has all the tools necessary

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Near Miss / Hit Reporting - Your Early Warning System

Most organisations I come across are good at recording and investigating their recordable and lost time accidents and a few record their First Aid cases as well. However, not many organisations have an effective system in place for the routine reporting and recording of Near Misses.

What's a Near Miss / Near Hit? Usually a near miss or hit is defined as an accident that almost happened. For example, the situation where someone trips and almost falls down the stairs but manages to grab the hand rail just in time, or when someone is almost hit by a reversing fork lift. In these two examples no injury resulted but this was the result of good luck rather than good management.

Why are Near Misses Important? In the simple examples given above, if an injury had resulted, most organisations would have carried out an investigation into the circumstances and would have taken some form of corrective action. In other words, the decision to investigate and take corrective action is based on whether a person has been injured or not. So therefore, if no injury occurs, no investigation takes place and **no attempt is made to prevent the same event occurring at some time in the future**.

What we are really saying is that we won't investigate and take corrective action until a serious injury or major damage occurs. Crazy, but then that is how many organisations operate unless they have a near miss reporting system.

When near misses occur they can be regarded as early warnings that something is wrong somewhere in the system. We therefore need to develop a system which allows us to take action before an injury takes place - and of course, this is nothing other than **good management practice**.

Implementing a Near Miss Reporting System. The first thing to do is to explain to all employees what near misses are and why they are important. Next, explain to them how Hazards & Near Misses will be reported and the forms to be used.

Once the system has been implemented make sure that report forms are readily available in the workplace - have a pad in the lunch room or by the safety notice board. (Keeping the reporting forms in the supervisor's office defeats the object of the exercise.)

When a Hazard and Near Miss report is received by a supervisor, the supervisor should discuss it with the person making the report, decide what corrective action should be taken and **implement the change as soon as possible** if it is within the supervisor's authority. If not, the matter should be referred to the manager for correction. Near Miss reports and recommended corrective action should not be deferred until the next committee meeting unless it requires further discussion. The idea is to **take immediate corrective action now**.

Many accidents can be prevented by taking prompt action to prevent a hazardous situation from continuing or developing into something worse. Therefore, use Near Miss reports as your early warning system - waiting for the injury to happen before acting just doesn't make sense!!!

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Tool Box Meetings for Team Building and Commitment

Holding tool box meetings is an excellent and quick way of increasing safety involvement and awareness at grass roots level. However, there are a few simple tips to follow if you want to use this tool effectively.

First of all toolbox meetings are usually run in small work groups by the supervisor, leading hand, team leader etc. of the group. The meetings are short, about 5 to 10 minutes, and informal.

The basic idea is to provide a direct method of communication and exchange of information between management, supervision and the shop floor with the purpose of improving safety and health by directly involving workers in issues that are important to them. Using tool box meetings is an ideal way to get employees involved in matters relating to their own safety, finding solutions to problems, as well as building a committed and productive team.

Tool box meetings can also be used to deliver training and to remind your people about on the job safety. But, please, keep the training short, snappy and to the point - using the prepared AchieveSafety Tool Box talk material will make this easy for you.

Clearly, employee input is essential in developing effective safety solutions and in the continual improvement process of improving on the job safety. Here are a few pointers:

Organisation of Meetings

- Tool box meetings should be held at regular intervals, be informal and sometimes impromptu, with some meetings being held as the need arises.
- Meetings may be run by managers, supervisors, leading hands, team leaders, health and safety committee members or by an employee who has an important issue for discussion.
- Meetings can be held anywhere provided there's enough space, it's quiet enough and it won't interfere with other people working nearby but not attending the meeting.
- Formal meeting rooms are not necessary, hence the title, "tool box" meetings.
- Tool box meetings normally last from 5 to 10 minutes. They are not meant to be a lengthy training session but rather a quick exchange of ideas on how some aspect or aspects of safety can be improved or fixed.
- A brief written record of the meeting should be kept together with the names of attendees, points raised and conclusions reached being recorded.

Suggested Topics for Discussion

- the causes of recent workplace accidents, injuries, near misses and possible preventive actions to be taken
- feedback on safety performance e.g. Lost Time Injury Frequency & Incidence Rates
- raising people's awareness of their responsibility for working safely e.g. housekeeping, wearing personal protective equipment, following the rules and procedures etc.
- invite people to raise safety issues about which they are concerned
- invite comment on workplace modification, new plant or equipment
- ask for employee input on reducing manual handling problems or how to modify tasks to reduce risks.

For more information on this topic see Tool Box Talks

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Fire Prevention

The risk of fire is present in all workplaces and it is important that everyone is aware of this hazard and knows what should be done to minimise the chance of fire. Here are a few reminders:

- observe "No Smoking" signs
- don't allow rubbish, old packaging materials, broken pallets, waste oil etc. to accumulate in work or storage areas
- don't allow flammable material, particularly stacked pallets, to be stored against outside walls
- store and handle flammable liquids safely; keep naked lights and sparks away
- provide metal, not plastic, waste bins; empty when three quarters full
- store oily rags and waste in metal bins with a lid
- don't use sawdust to absorb oil spills; use OilSorb or atapulgite (kitty litter)
- inspect electrical fittings and keep them in good order
- avoid the use of adaptors and long or damaged power cables
- at the end of the day switch off all electrical equipment at the wall power point
- when welding, cutting or grinding clear area of combustible material before starting work
- know where the fire extinguishers are located, check that they have been serviced within the last year
- make sure all fire extinguishers are mounted on the wall and are easily accessible
- practice your emergency evacuation procedure at least once a year.

Make sure everyone knows:

- how to raise the alarm
- the location of extinguishers and hose reels
- what extinguisher to use on different types of fire
- how to use each type of extinguisher
- location of nearest fire exit/s
- the assembly area.

FIRE DRILLS / FIRE PUMP TEST
RISER LOCATIONS
SYMESE LOCATION

FIRE PREVENTION

1- WALK UP TO YOUR BLDG
! LOOK !

2- FIRE PANEL / FIRE PUMP
DAILY OPERATIONAL + FREE OF TROUBLES
ALARMS

3. ACCESS NOT BLOCKED
STAIRWAYS
EXITS

4. TRASH STORED MATERIAL
RAGS - ECT

5- 911 Call if smoke / Fire
Look after

6- SIZE BIGGER THAN YOU CLOSE DOORS
SET ALARM PULL STATION -- EVACUATE.

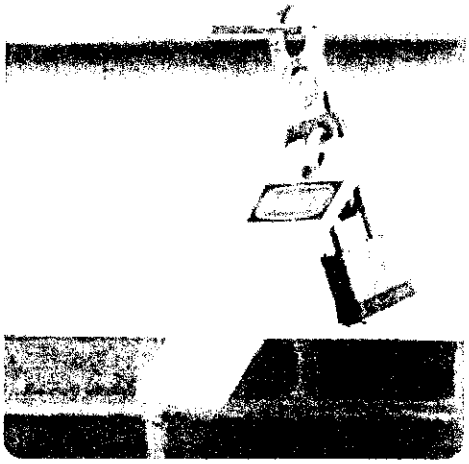
7- MEET FIRE DEPT OUTSIDE

Buzzle

What is Lockout/Tagout?

There are various safety measures that an organization should implement to ensure that its workers are not put to any risk of injury. Lockout/Tagout is one such procedure that is used in organizations dealing with heavy machinery and equipment.

Lockout/Tagout is a series of procedures laid down by the Occupational Safety and Health Administration under Title 29 Code of Federal Regulations (CFR) Part 1910.147. This regulation helps safeguard workers from the risks involved while dealing with servicing and maintenance of machinery and equipment. It has been estimated that Lockout/Tagout has helped prevent the loss of 120 fatalities and around 45,000 injuries every year since its inception. These figures can go up if all the organizations adhere to all rules and regulations religiously.



In a Lockout/Tagout program, all the power sources of a machine are locked so that these can't be activated and then the locks are tagged so that the message is conveyed to everyone that the maintenance activities are being carried out. This ensures that nobody turns on the power supplies accidentally, which in turn reduces the risk of accidents.

Lockout/Tagout procedures are to be implemented in every industry in which servicing and maintenance of large machines is required. Before these procedures came into effect, a lot of workers used to die of injuries sustained while repairing machinery or by getting an electric shock.

Tips for Employers

It is the responsibility of the employer that the workers are well aware of all the rules and regulations regarding workplace safety. Employers also need to ensure that they have an energy control program in place which prevents the workers from the risks of hazardous energy. Some of the things that can help employers to comply with the Lockout/Tagout program are :

- The first and foremost thing that an employer is expected to do is to develop an energy control program. He can then conduct a training program so that all the workers are aware of the safety procedures
- Employers can develop a written program enlisting the procedures of Lockout/Tagout and copies can be distributed to employees.
- Once the training is completed, ensure that the employee who is entrusted with Lockout/Tagout has undergone proper training under an approved energy control program.
- Employers should also ensure that worker who has applied the Lockout/Tagout only has the authorization to remove it.
- Employers can also review the safety modes employed annually and see whether the Lockout/Tagout procedures are in accordance with any new legislation introduced.

Tips for Workers

It is the responsibility of both employers and workers that all the safety measures including Lockout/Tagout are followed so that accidents and injuries can be decreased. Here are some tips:

- If you have been entrusted with the carrying out the Lockout/Tagout program, then always ensure that you do not share your lock or keys with anyone.
- Before starting the maintenance activities, ensure that the energy is completely dissipated and the machine is safe to be used.
- Lockout/Tagout devices should be compatible with the environment in which they have to be used.
- While restarting the equipment, ensure that the all the co-workers are at a safe distance from the equipment.

Common Mistakes to be Avoided

Despite all the rules and regulations that have been laid down for the safety of workers dealing maintenance of large machines, thousand of injuries still occur due to negligence and poor implementation of Lockout/Tagout procedures. Some common mistakes while Lockout/Tagout are :

- Some experienced workers feel that stopping and restarting the equipment consumes a lot of time and effects productivity. They feel that as they have spent a lot of time dealing with machines, they can handle the situation without following the Lockout/Tagout procedures.
- In most of the instance of injuries to workers, the alibi that one gets to hear frequently is that "I didn't know he was still in there". There is a high possibility that workers can be negligent while adopting the safety measures and can cause injury to their fellow workers.
- Telling co-workers who are not properly trained to remove the Lockout/Tagout has led to many incidents in the past, but this practice is still common in some organizations.
- Leaving the key in the lock while applying a Lockout/Tagout is another common mistake that workers make fearing they might misplace the key.

These were some of the common mistakes that are observed while carrying out the Lockout/Tagout. Lockout/Tagout procedures shouldn't be viewed as an unnecessary exercise as these have helped prevent many accidents in the past. Also, just agreeing to implement Lockout/Tagout doesn't assure one that there would no longer be any workplace accidents.

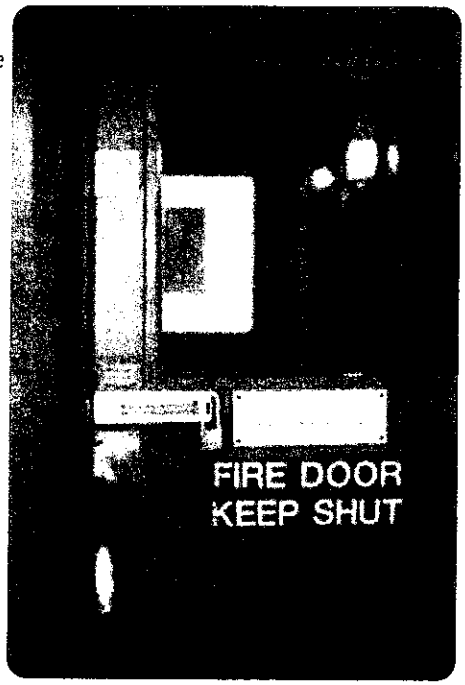
By Rahul Pandita
Last Updated: 10/8/2011

Buzzle

Fire-Rated Doors

This article tells you about fire rated doors that are observed in corporate houses, public buildings, and dormitories etc. for safety reasons.

There was too mush of rush in the theater as it was a weekend. People booked the tickets and went inside the theater. The movie started in couple of minutes. It was a comic movie and all of them were enjoying it, laughing aloud. After an hour suddenly there was a chaos in the theater and everyone started running towards the exit door. Before they all figured out the matter, the theater was half burned and the fire was catching up rapidly. The security directed the crowd to the stairways, from where everyone started going out of the theater. After twenty minutes, the whole theater was vacant and all the people were rescued safely.



Apart from the security and rescue people what played a major role in safety of the people is fire rated doors. The theater was equipped with fire rated doors that were installed in stairwells. If the doors did not exist, there were chances of mass casualties and human loss. This article tells you about fire rated doors that are one of the important parts of fire safety measures in public places.

What is a Fire-Rated Door?

Fire rated doors look like any other regular door but they are made of very heavy materials, such as metal, timber, steel, vermiculite boards, glass, or gypsum. Most of the fire doors are made using the combination of aforementioned materials. The primary function of these doors is to block back the smoke or fire between compartments or a place of fire ignition, so that the people can save themselves from that place safely. These doors are generally noncombustible and have the capacity to hold the average fire for a certain time period. The time period ranges from 20-90 minutes depending on the area of the building structure and the quality of the door you buy. But it is essential for the fire rate doors to meet the guidelines of the testing agency that determines if the door is really a fire resistant or not.

Fireproof Design of Fire-Rated Doors

You must be wondering how can a simple door hold back the fire. Well, the credit goes to design and materials used in the door. As said above, all the parts of the door, from its frame to the latch, everything has to be tested. All the components need to pass the product certification requirements that are approved by the local authority having jurisdiction, local building code, and the fire code etc. Hence fire rated doors are designed and manufactured with great care and precision. The frames of fire rated doors are endowed with fire seals that prevent the fire to spread outside the door. The leaf of the door is also made of materials that prevent the fire or can survive the fire without leaking the fire. The

hinges, latch, and door knobs too have to undergo the strenuous fire resistance tests. These doors are installed in walls known as fire walls that too need to be tested for fire and combustion. The fireproof design of fire rated doors converts an ordinary door in to a best passive fire protection system.

Designs in Fire-Rated Doors

Well tested fire rated doors are increasingly becoming the staple of modern furniture. They have come a long way and are now available in various designs, materials and advanced technology that can suit the physical structure of the office, theater, mall, and even your residence. Most of the fire doors come with automatic shut system. These doors get locked when the fire is detected by a fire sensor system. Due to this, you can keep the door open during other times. You do not have to sacrifice beauty for safety. Fire rated doors with glass are more common in workplace settings and corporate companies but residential fire rated doors are generally in wood as they suit almost any kind of home interior designs. Many fire doors come with a built-in window that too is fire tested. You can contact the local dealer to find out more designs and features.

Prevention is better than cure and hence installing fire rated doors at public places is always a smart option. But, remember that in case of an accident trusting fire rated doors completely is not a wise thought, instead make sure that you get out of the building as soon as possible for your safety.

By Geeta Dhavale
Published: 12/18/2010

Buzzle

Fire Safety Tips

Know how you can protect your family when fire breaks out. Follow these simple and easy tips and better protect life and property.

Hope for the best and prepare for the worst is the thing to be remembered in fire safety. Everyone knows that fire can be constructive as well as destructive, but the real key in protecting oneself and one's family from fire is staying prepared. Fire can start anywhere, in your home, office, school, hospital, etc. and the important thing to keep in mind about fire is that it can destroy things within seconds. It is thus of the greatest importance that you follow the fire safety tips and protect yourself and your family. Action on time and preventive measures can save your valuable property and life from being destroyed in fire.

Different types of fire can engulf a home or an office; fire can start from;

- Badly maintained electrical appliances
- Complete carelessness in fire protection.
- Mishandling inflammable liquids

In order to prevent fire from getting started one can follow tips like properly storing the gasoline which is the most inflammable liquid. Never ever keep gasoline in such a way that children can play with it; gasoline is only for cars. Preventive fire tips are;

- Replace the cords whose insulation cover has come off
- Do not Overload Electrical Appliances
- Smoke and burning smell from the appliances can cause fire
- Take the help of professionals if you think that there is something wrong with the appliances.

Practical Tips for Fire Safety at Home

One of the best and safest ways to prevent fire from taking place in your home is to have fire alarms in different corners of the home. Smoke alarms or fire alarms help in the detection of fire. There are smoke alarms that don't need much maintenance and can last up to 10 years and there are also the battery operated smoke alarms. Smoke alarms must be kept clean from dust and tested from time to time so that they keep on working when actual fire breaks out. A battery powered smoke alarm needs a battery change a year.

One can have an emergency evacuation plan ready and practicing how to escape from the home when the fire breaks out will always keep all the family members ready for an emergency. All the exit or the escape places must be kept clear so that when there is fire one can easily get out of the house. Members of the family should be able to access keys to the doors in case of fire so that no gets trapped in the house.

Most often the source of fire in a home is the kitchen so care should be taken while cooking. Blow out candles when not needed. Candles must be kept in such a place that if they fall down the material should not catch fire. If you are a smoker don't smoke in bed. Put out the cigarette completely when you have finished with it. If you are drunk be careful with things lest you may cause fire. If you are not watching the television or using the computer switch it off so that no fire breaks out.

Safety Tips for Fire in the Office

An office is another place where the occurrence of fire is always expected. If a fire breaks out one must know the possible exit places of the building. Following are some of the tips to use in an emergency.

- Get familiar with the emergency rescue plan of the building
- One should be able to recognize the fire alarms installed in the building
- Never try to walk in the smoke, rather crawl and find ways to escape
- Avoid the elevator completely
- Watch before you touch the handle of any door
- Stay calm and don't panic at all

By Rahul Dhembare
Published: 8/31/2007

Bacteria

From Wikipedia, the free encyclopedia

Bacteria (/bækˈtɪəriə/; *singular*: **bacterium**) constitute a large domain of prokaryotic microorganisms. Typically a few micrometres in length, bacteria have a wide range of shapes, ranging from spheres to rods and spirals. Bacteria were among the first life forms to appear on Earth, and are present in most habitats on the planet. Bacteria inhabit soil, water, acidic hot springs, radioactive waste,[2] and the deep portions of Earth's crust. Bacteria also live in plants, animals (see symbiosis), and have survived in space.[3]

There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a millilitre of fresh water. There are approximately 5×10^{30} bacteria on Earth,[4] forming a biomass that exceeds that of all plants and animals.[5] Bacteria are vital in recycling nutrients, with many steps in nutrient cycles depending on these organisms, such as the fixation of nitrogen from the atmosphere and putrefaction. In the biological communities surrounding hydrothermal vents and cold seeps, bacteria provide the nutrients needed to sustain life by converting dissolved compounds such as hydrogen sulphide and methane to energy. On 17 March 2013, researchers reported data that suggested bacterial life forms thrive in the Mariana Trench, the deepest spot on the Earth.[6][7] Other researchers reported related studies that microbes thrive inside rocks up to 1900 feet below the sea floor under 8500 feet of ocean off the coast of the northwestern United States.[6][8] According to one of the researchers,"You can find microbes everywhere — they're extremely adaptable to conditions, and survive wherever they are."[6]

Most bacteria have not been characterised, and only about half of the phyla of bacteria have species that can be grown in the laboratory.[9] The study of bacteria is known as bacteriology, a branch of microbiology.

There are approximately ten times as many bacterial cells in the human flora as there are human cells in the body, with large numbers of bacteria on the skin and as gut flora.[10] The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, and a few are beneficial. However, a few species of bacteria are pathogenic and cause infectious diseases, including

Bacteria

Temporal range:

Archean or earlier – Recent

Had'n Archean Proterozoic Pha.

Scanning electron micrograph of *Escherichia coli* bacilli

Scientific classification

Domain: **Bacteria**

Phyla[1]

- **Gram positive / no outer membrane**

Actinobacteria (high-G+C)
Firmicutes (low-G+C)
Tenericutes (no wall)

- **Gram negative / outer membrane present**

Aquificae
Deinococcus-Thermus
Fibrobacteres–Chlorobi/Bacteroidetes (FCB group)
Fusobacteria
Gemmatimonadetes
Nitrospirae
Planctomycetes–Verrucomicrobia/Chlamydiae

cholera, syphilis, anthrax, leprosy, and bubonic plague. The most common fatal bacterial diseases are respiratory infections, with tuberculosis alone killing about 2 million people a year, mostly in sub-Saharan Africa.[11] In developed countries, antibiotics are used to treat bacterial infections and in agriculture, so antibiotic resistance is becoming common. In industry, bacteria are important in sewage treatment and the breakdown of oil spills, the production of cheese and yogurt through fermentation, the recovery of gold, palladium, copper and other metals in the mining sector,[12] as well as in biotechnology, and the manufacture of antibiotics and other chemicals.[13]

(PVC group)
Proteobacteria
Spirochaetes
Synergistetes

- **Unknown / ungrouped**

Acidobacteria
Chloroflexi
Chrysiogenetes
Cyanobacteria
Deferribacteres
Dictyoglomi
Thermodesulfobacteria
Thermotogae

Once regarded as plants constituting the class *Schizomycetes*, bacteria are now classified as prokaryotes. Unlike cells of animals and other eukaryotes, bacterial cells do not contain a nucleus and rarely harbour membrane-bound organelles. Although the term *bacteria* traditionally included all prokaryotes, the scientific classification changed after the discovery in the 1990s that prokaryotes consist of two very different groups of organisms that evolved from an ancient common ancestor. These evolutionary domains are called Bacteria and Archaea.[14]

Contents

- 1 Etymology
- 2 Origin and early evolution
- 3 Morphology
- 4 Cellular structure
  - 4.1 Intracellular structures
  - 4.2 Extracellular structures
  - 4.3 Endospores
- 5 Metabolism
- 6 Growth and reproduction
- 7 Genetics
  - 7.1 DNA transfer
  - 7.2 Bacteriophages
- 8 Behavior
  - 8.1 Secretion
  - 8.2 Bioluminescence
  - 8.3 Multicellularity
  - 8.4 Movement
- 9 Classification and identification
- 10 Interactions with other organisms
  - 10.1 Predators
  - 10.2 Mutualists
  - 10.3 Pathogens
- 11 Significance in technology and industry

- 12 History of bacteriology
- 13 See also
- 14 References
- 15 Further reading
- 16 External links

Etymology

The word *bacteria* is the plural of the New Latin *bacterium*, which is the latinisation of the Greek βακτήριον (*baktērion*),[15] the diminutive of βακτηρία (*baktēria*), meaning "staff, cane",[16] because the first ones to be discovered were rod-shaped.[17]

Origin and early evolution

Further information: Timeline of evolution and Evolutionary history of life

The ancestors of modern bacteria were single-celled microorganisms that were the first forms of life to appear on Earth, about 4 billion years ago. For about 3 billion years, all organisms were microscopic, and bacteria and archaea were the dominant forms of life.[18][19] Although bacterial fossils exist, such as stromatolites, their lack of distinctive morphology prevents them from being used to examine the history of bacterial evolution, or to date the time of origin of a particular bacterial species. However, gene sequences can be used to reconstruct the bacterial phylogeny, and these studies indicate that bacteria diverged first from the archaeal/eukaryotic lineage.[20]

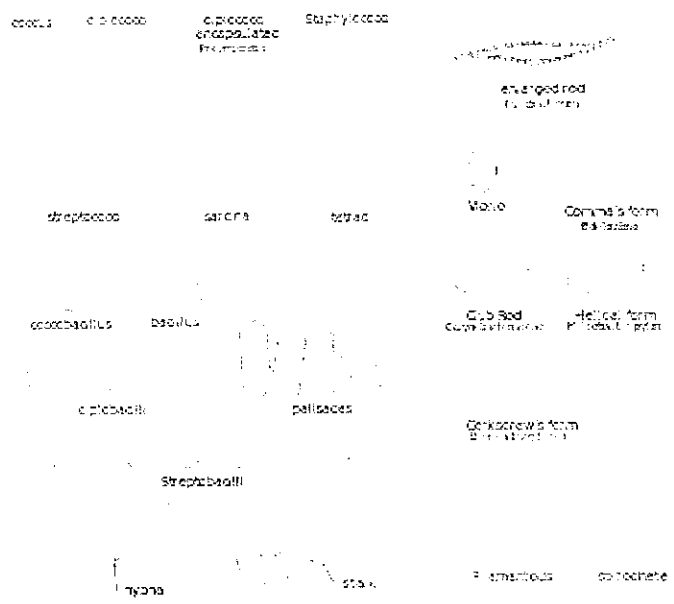
Bacteria were also involved in the second great evolutionary divergence, that of the archaea and eukaryotes. Here, eukaryotes resulted from ancient bacteria entering into endosymbiotic associations with the ancestors of eukaryotic cells, which were themselves possibly related to the Archaea.[21][22] This involved the engulfment by proto-eukaryotic cells of alpha-proteobacterial symbionts to form either mitochondria or hydrogenosomes, which are still found in all known Eukarya (sometimes in highly reduced form, e.g. in ancient "amitochondrial" protozoa). Later on, some eukaryotes that already contained mitochondria also engulfed cyanobacterial-like organisms. This led to the formation of chloroplasts in algae and plants. There are also some algae that originated from even later endosymbiotic events. Here, eukaryotes engulfed a eukaryotic algae that developed into a "second-generation" plastid.[23][24] This is known as secondary endosymbiosis.

Morphology

Further information: Bacterial cellular morphologies

Bacteria display a wide diversity of shapes and sizes, called *morphologies*. Bacterial cells are about one tenth the size of eukaryotic cells and are typically 0.5–5.0 micrometres in length. However, a few species — for example, *Thiomargarita namibiensis* and *Epulopiscium fishelsoni* — are up to half a millimetre long and are visible to the unaided eye;[25] *E. fishelsoni* reaches 0.7 mm.[26] Among the

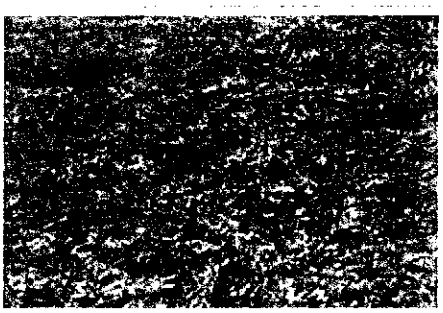
smallest bacteria are members of the genus *Mycoplasma*, which measure only 0.3 micrometres, as small as the largest viruses.[27] Some bacteria may be even smaller, but these ultramicrobacteria are not well-studied.[28]



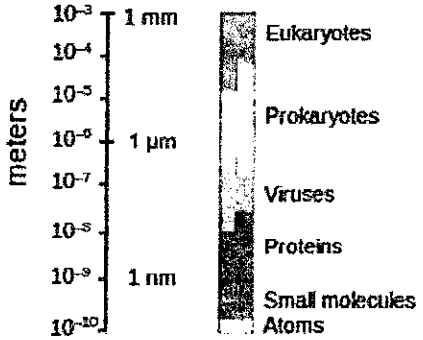
Bacteria display many cell morphologies and arrangements

Most bacterial species are either spherical, called **cocci** (*sing.* coccus, from Greek *κόκκος-kókkos*, grain, seed), or rod-shaped, called **bacilli** (*sing.* bacillus, from Latin *baculus*, stick). Elongation is associated with swimming.[29] Some rod-shaped bacteria, called **vibrio**, are slightly curved or comma-shaped; others can be spiral-shaped, called **spirilla**, or tightly coiled, called **spirochaetes**. A small number of species even have tetrahedral or cuboidal shapes.[30] More recently, bacteria were discovered deep under the Earth's crust that grow as long rods with a star-shaped cross-section. The large surface area to volume ratio of this morphology may give these bacteria an advantage in nutrient-poor environments.[31] This wide variety of shapes is determined by the bacterial cell wall and cytoskeleton, and is important because it can influence the ability of bacteria to acquire nutrients, attach to surfaces, swim through liquids and escape predators.[32][33]

Many bacterial species exist simply as single cells, others associate in characteristic patterns: *Neisseria* form diploids (pairs), *Streptococcus* form chains, and *Staphylococcus* group together in "bunch of grapes" clusters. Bacteria can also be elongated to form filaments, for example the Actinobacteria. Filamentous bacteria are often surrounded by a sheath that contains many individual cells. Certain types, such as species of the genus *Nocardia*, even form complex, branched filaments, similar in appearance to fungal mycelia.[34]

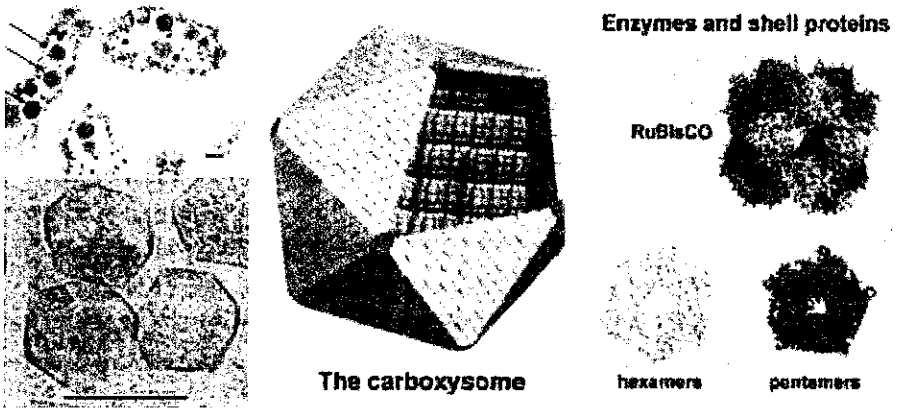


A biofilm of thermophilic bacteria in the outflow of Mickey Hot Springs, Oregon, approximately 20 mm thick.



Bacteria often attach to surfaces and form dense aggregations called **biofilms** or bacterial mats. These films can range from a few micrometers in thickness to up to half a meter in depth, and may contain multiple species of bacteria, protists and archaea. Bacteria living in biofilms display a complex arrangement of cells and extracellular components, forming secondary structures such as microcolonies, through which there are networks of channels to enable better diffusion of nutrients.[35][36] In natural environments, such as soil or the surfaces of plants, the majority

cell with layers of light-gathering membrane.[50] These light-gathering complexes may even form lipid-enclosed structures called chlorosomes in green sulfur bacteria.[51] Other proteins import nutrients across the cell membrane, or expel undesired molecules from the cytoplasm.



Carboxysomes are protein-enclosed bacterial organelles. Top left is an electron microscope image of carboxysomes in *Halothiobacillus neapolitanus*, below is an image of purified carboxysomes. On the right is a model of their structure. Scale bars are 100 nm.[52]

Most bacteria do not have a membrane-bound nucleus, and their genetic material is typically a single circular chromosome located in the cytoplasm in an irregularly shaped body called the **nucleoid**.[53] The nucleoid contains the chromosome with its associated proteins and RNA. The order Planctomycetes are an exception to the general absence of internal membranes in bacteria, because they have a double membrane around their nucleoids and contain other membrane-bound cellular structures.[54] Like all living organisms, bacteria contain **ribosomes**, often grouped in chains called polyribosomes, for the production of proteins, but the structure of the bacterial ribosome is different from that of eukaryotes and Archaea.[55]

Some bacteria produce intracellular nutrient storage granules for later use, such as glycogen,[56] polyphosphate,[57] sulfur[58] or polyhydroxyalkanoates.[59] Certain bacterial species, such as the photosynthetic Cyanobacteria, produce internal gas vesicles, which they use to regulate their buoyancy – allowing them to move up or down into water layers with different light intensities and nutrient levels.[60] **Intracellular membranes** called **chromatophores** are also found in membranes of phototrophic bacteria. Used primarily for photosynthesis, they contain bacteriochlorophyll pigments and carotenoids. An early idea was that bacteria might contain membrane folds termed mesosomes, but these were later shown to be artifacts produced by the chemicals used to prepare the cells for electron microscopy. **Inclusions** are considered to be nonliving components of the cell that do not possess metabolic activity and are not bounded by membranes. The most common inclusions are glycogen, lipid droplets, crystals, and pigments. **Volutin granules** are cytoplasmic inclusions of complexed inorganic polyphosphate. These granules are called **metachromatic granules** due to their displaying the metachromatic effect; they appear red or blue when stained with the blue dyes methylene blue or toluidine blue. **Gas vacuoles**, which are freely permeable to gas, are membrane-bound vesicles present in some species of *Cyanobacteria*. They allow the bacteria to control their buoyancy. **Microcompartments** are widespread, membrane-bound organelles that are made of a protein shell that surrounds and encloses various enzymes. **Carboxysomes** are bacterial microcompartments that contain enzymes involved in carbon fixation. **Magnetosomes** are bacterial microcompartments, present in magnetotactic bacteria, that contain magnetic crystals.

Extracellular structures

Further information: Cell envelope

In most bacteria a **cell wall** is present on the outside of the cytoplasmic membrane. The plasma membrane and cell wall comprise the **cell envelope**. A common bacterial cell wall material is **peptidoglycan** (called "murein" in older sources), which is made from polysaccharide chains cross-linked by peptides containing D-amino acids.[61] Bacterial cell walls are different from the cell walls of plants and fungi, which are made of cellulose and chitin, respectively.[62] The cell wall of bacteria is also distinct from that of Archaea, which do not contain peptidoglycan. The cell wall is essential to the survival of many bacteria, and the antibiotic penicillin is able to kill bacteria by inhibiting a step in the synthesis of peptidoglycan.[62]

There are broadly speaking two different types of cell wall in bacteria, called Gram-positive and Gram-negative. The names originate from the reaction of cells to the Gram stain, a test long-employed for the classification of bacterial species.[63]

Gram-positive bacteria possess a thick cell wall containing many layers of peptidoglycan and **teichoic acids**. In contrast, **Gram-negative bacteria** have a relatively thin cell wall consisting of a few layers of peptidoglycan surrounded by a second lipid membrane containing **lipopolysaccharides** and lipoproteins. Lipopolysaccharides, also called **endotoxins**, are composed of polysaccharides and **lipid A** (responsible for much of the toxicity of Gram-negative bacteria). Most bacteria have the Gram-negative cell wall, and only the Firmicutes and Actinobacteria (previously known as the low G+C and high G+C Gram-positive bacteria, respectively) have the alternative Gram-positive arrangement.[64] These differences in structure can produce differences in antibiotic susceptibility; for instance, vancomycin can kill only Gram-positive bacteria and is ineffective against Gram-negative pathogens, such as *Haemophilus influenzae* or *Pseudomonas aeruginosa*.[65] If the bacterial cell wall is entirely removed, it is called a **protoplast** while if it's partially removed, it is called a **spheroplast**. β-Lactam antibiotics such as penicillin inhibit the formation of peptidoglycan cross-links in the bacterial cell wall. The enzyme lysozyme, found in human tears, also digests the cell wall of bacteria and is the body's main defense against eye infections. **Acid-fast bacteria**, like *Mycobacteria*, are resistant to decolorization by acids during staining procedures. The high mycolic acid content of *Mycobacteria*, is responsible for the staining pattern of poor absorption followed by high retention. The most common staining technique used to identify acid-fast bacteria is the Ziehl-Neelsen stain or acid-fast stain, in which the acid fast bacilli are stained bright red and stand out clearly against a blue background. **L-form bacteria** are strains of bacteria that lack cell walls. The main pathogenic bacteria in this class is *Mycoplasma* (not to be confused with *Mycobacteria*).

In many bacteria an **S-layer** of rigidly arrayed protein molecules covers the outside of the cell.[66] This layer provides chemical and physical protection for the cell surface and can act as a macromolecular diffusion barrier. S-layers have diverse but mostly poorly understood functions, but are known to act as virulence factors in *Campylobacter* and contain surface enzymes in *Bacillus stearothermophilus*.[67]

Flagella are rigid protein structures, about 20 nanometres in diameter and up to 20 micrometres in length, that are used for motility. Flagella are driven by the energy released by the transfer of ions down an electrochemical gradient across the cell membrane.[68]

Helicobacter pylori electron micrograph, showing multiple flagella on the cell surface

Fimbriae (sometimes called "attachment pili") are fine filaments of protein, just 2–10 nanometres in diameter and up to several micrometers in length. They are distributed over the surface of the cell, and resemble fine hairs when seen under the electron microscope. Fimbriae are believed to be involved in attachment to solid surfaces or to other cells and are essential for the virulence of some bacterial pathogens.[69] **Pili** (*sing.* pilus) are cellular appendages, slightly larger than fimbriae, that can transfer genetic material between bacterial cells in a process called conjugation where they are called **conjugation pili** or "sex pili" (see bacterial genetics, below).[70] They can also generate movement where they are called **type IV pili** (see movement, below).

Glycocalyx are produced by many bacteria to surround their cells, and vary in structural complexity: ranging from a disorganised **slime layer** of extra-cellular polymer, to a highly structured **capsule**. These structures can protect cells from engulfment by eukaryotic cells, such as macrophages.[71] They can also act as antigens and be involved in cell recognition, as well as aiding attachment to surfaces and the formation of biofilms.[72]

The assembly of these extracellular structures is dependent on bacterial secretion systems. These transfer proteins from the cytoplasm into the periplasm or into the environment around the cell. Many types of secretion systems are known and these structures are often essential for the virulence of pathogens, so are intensively studied.[73]

Endospores

Further information: Endospores

Certain genera of Gram-positive bacteria, such as *Bacillus*, *Clostridium*, *Sporohalobacter*, *Anaerobacter* and *Heliobacterium*, can form highly resistant, dormant structures called **endospores**.[74] In almost all cases, one endospore is formed and this is not a reproductive process, although *Anaerobacter* can make up to seven endospores in a single cell.[75] Endospores have a central core of cytoplasm containing DNA and ribosomes surrounded by a cortex layer and protected by an impermeable and rigid coat. Dipicolinic acid is a chemical compound which composes 5% to 15% of the dry weight of bacterial spores. It is implicated as responsible for the heat resistance of the endospore.

Bacillus anthracis (stained purple) growing in cerebrospinal fluid

Endospores show no detectable metabolism and can survive extreme physical and chemical stresses, such as high levels of UV light, gamma radiation, detergents, disinfectants, heat, freezing, pressure and desiccation.[76] In this dormant state, these organisms may remain viable for millions of years,[77][78] and endospores even allow bacteria to survive exposure to the vacuum and radiation in space.[79] According to scientist Dr. Steinn Sigurdsson, "There are viable bacterial spores that have been found that are 40

million years old on Earth — and we know they're very hardened to radiation."[80] Endospore-forming bacteria can also cause disease: for example, anthrax can be contracted by the inhalation of *Bacillus anthracis* endospores, and contamination of deep puncture wounds with *Clostridium tetani* endospores causes tetanus.[81]

Metabolism

Further information: Microbial metabolism

Bacteria exhibit an extremely wide variety of metabolic types.[82] The distribution of metabolic traits within a group of bacteria has traditionally been used to define their taxonomy, but these traits often do not correspond with modern genetic classifications.[83] Bacterial metabolism is classified into nutritional groups on the basis of three major criteria: the kind of energy used for growth, the source of carbon, and the electron donors used for growth. An additional criterion of respiratory microorganisms are the electron acceptors used for aerobic or anaerobic respiration.[84]

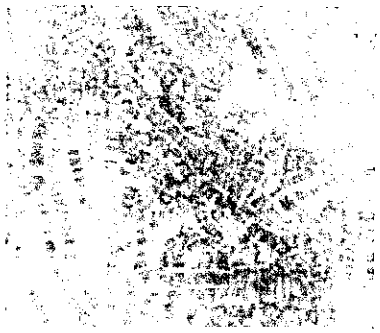
Nutritional types in bacterial metabolism

Nutritional type	Source of energy	Source of carbon	Examples
Phototrophs	Sunlight	Organic compounds (photoheterotrophs) or carbon fixation (photoautotrophs)	Cyanobacteria, Green sulfur bacteria, Chloroflexi, or Purple bacteria
Lithotrophs	Inorganic compounds	Organic compounds (lithoheterotrophs) or carbon fixation (lithoautotrophs)	Thermodesulfobacteria, *Hydrogenophilaceae*, or Nitrospirae
Organotrophs	Organic compounds	Organic compounds (chemoheterotrophs) or carbon fixation (chemoautotrophs)	*Bacillus*, *Clostridium* or *Enterobacteriaceae*

Carbon metabolism in bacteria is either **heterotrophic**, where organic carbon compounds are used as carbon sources, or **autotrophic**, meaning that cellular carbon is obtained by fixing carbon dioxide. Heterotrophic bacteria include parasitic types. Typical autotrophic bacteria are phototrophic cyanobacteria, green sulfur-bacteria and some purple bacteria, but also many chemolithotrophic species, such as nitrifying or sulfur-oxidising bacteria.[85] Energy metabolism of bacteria is either based on **phototrophy**, the use of light through photosynthesis, or based on **chemotrophy**, the use of chemical substances for energy, which are mostly oxidised at the expense of oxygen or alternative electron acceptors (aerobic/anaerobic respiration).

Finally, bacteria are further divided into **lithotrophs** that use inorganic electron donors and **organotrophs** that use organic compounds as electron donors. Chemotrophic organisms use the respective electron donors for energy conservation (by aerobic/anaerobic respiration or fermentation) and biosynthetic reactions (e.g. carbon dioxide fixation), whereas phototrophic organisms use them only for biosynthetic purposes. Respiratory organisms use chemical compounds as a source of energy by taking electrons from the reduced substrate and transferring them to a terminal electron acceptor in a redox reaction. This reaction releases energy that can be used to synthesise ATP and drive metabolism.

In **aerobic organisms**, oxygen is used as the electron acceptor. In **anaerobic organisms** other inorganic compounds, such as nitrate, sulfate or carbon dioxide are used as electron acceptors. This leads to the ecologically important processes of denitrification, sulfate reduction and acetogenesis, respectively.



Filaments of photosynthetic cyanobacteria

Another way of life of chemotrophs in the absence of possible electron acceptors is fermentation, where the electrons taken from the reduced substrates are transferred to oxidised intermediates to generate reduced fermentation products (e.g. lactate, ethanol, hydrogen, butyric acid). Fermentation is possible, because the energy content of the substrates is higher than that of the products, which allows the organisms to synthesise ATP and drive their metabolism.[86][87]

These processes are also important in biological responses to pollution; for example, sulfate-reducing bacteria are largely responsible for the production of the highly toxic forms of mercury (methyl- and dimethylmercury) in the environment.[88] Non-respiratory anaerobes use fermentation to generate energy and reducing power, secreting metabolic by-products (such as ethanol in brewing) as waste. Facultative anaerobes can switch between fermentation and different terminal electron acceptors depending on the environmental conditions in which they find themselves.

Lithotrophic bacteria can use inorganic compounds as a source of energy. Common inorganic electron donors are hydrogen, carbon monoxide, ammonia (leading to nitrification), ferrous iron and other reduced metal ions, and several reduced sulfur compounds. Unusually, the gas methane can be used by methanotrophic bacteria as both a source of electrons and a substrate for carbon anabolism.[89] In both aerobic phototrophy and chemolithotrophy, oxygen is used as a terminal electron acceptor, while under anaerobic conditions inorganic compounds are used instead. Most lithotrophic organisms are autotrophic, whereas organotrophic organisms are heterotrophic.

In addition to fixing carbon dioxide in photosynthesis, some bacteria also fix nitrogen gas (nitrogen fixation) using the enzyme nitrogenase. This environmentally important trait can be found in bacteria of nearly all the metabolic types listed above, but is not universal.[90]

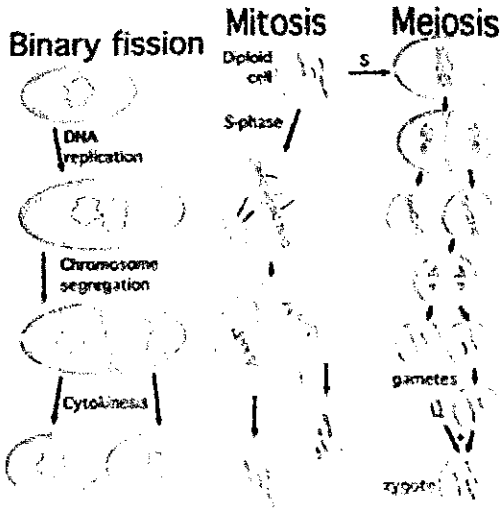
Regardless of the type of metabolic process they employ, the majority of bacteria are only able to take in raw materials in the form of relatively small molecules, which enter the cell by diffusion or through molecular channels in cell membranes. The Planctomycetes are the exception (as they are in possessing membranes around their nuclear material). It has recently been shown that *Gemmata obscuriglobus* is able to take in large molecules via a process that in some ways resembles endocytosis, the process used by eukaryotic cells to engulf external items.[26][91]

Growth and reproduction

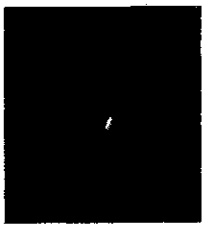
Further information: Bacterial growth

Unlike in multicellular organisms, increases in cell size (cell growth and reproduction by cell division) are tightly linked in unicellular organisms. Bacteria grow to a fixed size and then reproduce through **binary fission**, a form of asexual reproduction.[92] Under optimal conditions, bacteria can grow and

divide extremely rapidly, and bacterial populations can double as quickly as every 9.8 minutes.[93] In cell division, two identical clone daughter cells are produced. Some bacteria, while still reproducing asexually, form more complex reproductive structures that help disperse the newly formed daughter cells. Examples include fruiting body formation by *Myxobacteria* and aerial hyphae formation by *Streptomyces*, or budding. Budding involves a cell forming a protrusion that breaks away and produces a daughter cell.



Many bacteria reproduce through binary fission, which is compared to mitosis and meiosis in this image.



A colony of *Escherichia coli* [94]

In the laboratory, bacteria are usually grown using solid or liquid media. Solid **growth media** such as agar plates are used to isolate pure cultures of a bacterial strain. However, liquid growth media are used when measurement of growth or large volumes of cells are required. Growth in stirred liquid media occurs as an even cell suspension, making the cultures easy to divide and transfer, although isolating single bacteria from liquid media is difficult. The use of selective media (media with specific nutrients added or deficient, or with antibiotics added) can help identify specific organisms.[95]

Most laboratory techniques for growing bacteria use high levels of nutrients to produce large amounts of cells cheaply and quickly. However, in natural environments nutrients are limited, meaning that bacteria cannot continue to reproduce indefinitely. This nutrient limitation has led the evolution of different growth strategies (see r/K selection theory). Some organisms can grow extremely rapidly when nutrients become available, such as the formation of algal (and cyanobacterial) blooms that often occur in lakes during the summer.[96] Other organisms have adaptations to harsh environments, such as the production of multiple antibiotics by *Streptomyces* that inhibit the growth of competing microorganisms.[97] In nature, many organisms live in communities (e.g., biofilms) that may allow for increased supply of nutrients and protection from environmental stresses.[37] These relationships can be essential for growth of a particular organism or group of organisms (syntrophy).[98]

Bacterial growth follows four phases. When a population of bacteria first enter a high-nutrient environment that allows growth, the cells need to adapt to their new environment. The first phase of growth is the **lag phase**, a period of slow growth when the cells are adapting to the high-nutrient environment and preparing for fast growth. The lag phase has high biosynthesis rates, as proteins necessary for rapid growth are produced.[99] The second phase of growth is the **log phase**, also known as the *logarithmic or exponential phase*. The log phase is marked by rapid exponential growth. The rate at which cells grow during this phase is known as the *growth rate* (k), and the time it takes the cells to double is known as the *generation time* (g). During log phase, nutrients are metabolised at maximum speed until one of the nutrients is depleted and starts limiting growth. The third phase of growth is the **stationary phase** and is caused by depleted nutrients. The cells reduce their metabolic activity and consume non-essential cellular proteins. The stationary phase is a transition from rapid growth to a stress

response state and there is increased expression of genes involved in DNA repair, antioxidant metabolism and nutrient transport.[100] The final phase is the **death phase** where the bacteria runs out of nutrients and dies.

Genetics

Further information: Plasmid, Genome

Most bacteria have a single circular chromosome that can range in size from only 160,000 base pairs in the endosymbiotic bacteria *Candidatus Carsonella ruddii*,[101] to 12,200,000 base pairs in the soil-dwelling bacteria *Sorangium cellulosum*.[102] Spirochaetes of the genus *Borrelia* are a notable exception to this arrangement, with bacteria such as *Borrelia burgdorferi*, the cause of Lyme disease, containing a single linear chromosome.[103] The genes in bacterial genomes are usually a single continuous stretch of DNA and although several different types of introns do exist in bacteria, these are much more rare than in eukaryotes.[104]

Bacteria may also contain **plasmids**, which are small extra-chromosomal DNAs that may contain genes for antibiotic resistance or virulence factors.

Bacteria, as asexual organisms, inherit identical copies of their parent's genes (i.e., they are clonal). However, all bacteria can evolve by selection on changes to their genetic material DNA caused by genetic recombination or mutations. Mutations come from errors made during the replication of DNA or from exposure to mutagens. Mutation rates vary widely among different species of bacteria and even among different clones of a single species of bacteria.[105] Genetic changes in bacterial genomes come from either random mutation during replication or "stress-directed mutation", where genes involved in a particular growth-limiting process have an increased mutation rate.[106]

DNA transfer

Some bacteria also transfer genetic material between cells. This can occur in three main ways. First, bacteria can take up exogenous DNA from their environment, in a process called **transformation**. Genes can also be transferred by the process of **transduction**, when the integration of a bacteriophage introduces foreign DNA into the chromosome. The third method of gene transfer is **conjugation**, where DNA is transferred through direct cell contact.

Transduction of bacterial genes by bacteriophage appears to be a consequence of infrequent errors during intracellular assembly of virus particles, rather than a bacterial adaptation. Conjugation, in the well-studied E. coli system is determined by plasmid genes, and is an adaptation for transferring copies of the plasmid from one bacterial host to another. Infrequently, a conjugative plasmid may integrate into the host bacterial chromosome, and subsequently transfer part of the host bacterial DNA to another bacterium. Plasmid mediated transfer of host bacterial DNA also appears to be an accidental process rather than a bacterial adaptation.

Transformation, unlike transduction or conjugation, depends on numerous bacterial gene products that specifically interact to perform this complex process,[107] and thus transformation is clearly a bacterial adaptation for DNA transfer. In order for a bacterium to bind, take up and recombine donor DNA into its own chromosome, it must first enter a special physiological state termed competence (see Natural

competence). In *Bacillus subtilis* about 40 genes are required for the development of competence.[108] The length of DNA transferred during *B. subtilis* transformation can be between a third of a chromosome up to the whole chromosome.[109][110] Transformation appears to be common among bacterial species, and thus far at least 60 species are known to have the natural ability to become competent for transformation.[111] The development of competence in nature is usually associated with stressful environmental conditions, and seems to be an adaptation for facilitating repair of DNA damage in recipient cells.[112]

Ordinarily transduction, conjugation and transformation involve transfer of DNA between individual bacteria of the same species, but occasionally transfer may occur between individuals of different bacterial species and this may have significant consequences, such as the transfer of antibiotic resistance.[113] In such cases, gene acquisition from other bacteria or the environment is called **horizontal gene transfer** and may be common under natural conditions.[114] Gene transfer is particularly important in antibiotic resistance as it allows the rapid transfer of resistance genes between different pathogens.[115]

Bacteriophages

Main article: Bacteriophage

Bacteriophages are viruses that infect bacteria. Many types of bacteriophage exist, some simply infect and lyse their host bacteria, while others insert into the bacterial chromosome. A bacteriophage can contain genes that contribute to its host's phenotype: for example, in the evolution of *Escherichia coli* O157:H7 and *Clostridium botulinum*, the toxin genes in an integrated phage converted a harmless ancestral bacterium into a lethal pathogen.[116] Bacteria resist phage infection through restriction modification systems that degrade foreign DNA,[117] and a system that uses CRISPR sequences to retain fragments of the genomes of phage that the bacteria have come into contact with in the past, which allows them to block virus replication through a form of RNA interference.[118][119] This CRISPR system provides bacteria with acquired immunity to infection.

Behavior

Secretion

Bacteria frequently secrete chemicals into their environment in order to modify it favorably. The secretions are often proteins and may act as enzymes that digest some form of food in the environment.

Bioluminescence

Further information: Milky seas effect

A few bacteria have chemical systems that generate light. This bioluminescence often occurs in bacteria that live in association with fish, and the light probably serves to attract fish or other large animals.[120]

Multicellularity

See also: Prokaryote#Sociality

Bacteria often function as multicellular aggregates known as biofilms, exchanging a variety of molecular signals for inter-cell communication, and engaging in coordinated multicellular behavior.[121][122]

The communal benefits of multicellular cooperation include a cellular division of labor, accessing resources that cannot effectively be utilized by single cells, collectively defending against antagonists, and optimizing population survival by differentiating into distinct cell types.[121] For example, bacteria in biofilms can have more than 500 times increased resistance to antibacterial agents than individual "planktonic" bacteria of the same species.[122]

One type of inter-cellular communication by a molecular signal is called quorum sensing, which serves the purpose of determining whether there is a local population density that is sufficiently high that it is productive to invest in processes that are only successful if large numbers of similar organisms behave similarly, as in excreting digestive enzymes or emitting light.

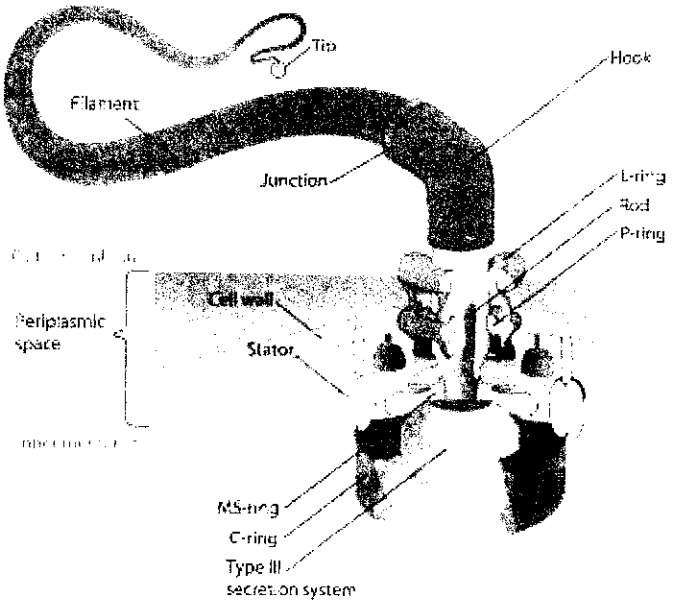
Quorum sensing allows bacteria to coordinate gene expression, and enables them to produce, release and detect autoinducers or pheromones which accumulate with the growth in cell population.[123]

Movement

Further information: Chemotaxis, Flagellum, Pilus

Many bacteria can move using a variety of mechanisms: flagella are used for swimming through fluids; bacterial gliding and twitching motility move bacteria across surfaces; and changes of buoyancy allow vertical motion.[124]

Swimming bacteria frequently move near 10 body lengths per second and a few as fast as 100. This makes them at least as fast as fish, on a relative scale.[125]



In bacterial gliding and twitching motility, bacteria use their **type IV pili** as a grappling hook, repeatedly extending it, anchoring it and then retracting it with remarkable force (>80 pN).[126]

> *"Our observations redefine twitching motility as a rapid, highly organized mechanism of bacterial translocation by which Pseudomonas aeruginosa can disperse itself over large areas to colonize new territories. It is also now clear, both morphologically and genetically, that twitching motility and*

social gliding motility, such as occurs in Myxococcus xanthus, are essentially the same process."
—"A re-examination of twitching motility in *Pseudomonas aeruginosa*" - Semmler, Whitchurch & Mattick (1999) (http://mic.sgmjournals.org/content/145/10/2863.full)

Flagellum of Gram-negative Bacteria. The base drives the rotation of the hook and filament.

Flagella are semi-rigid cylindrical structures that are rotated and function much like the propeller on a ship. Objects as small as bacteria operate a low Reynolds number and cylindrical forms are more efficient than the flat, paddle-like, forms appropriate at human size scale.[127]

Bacterial species differ in the number and arrangement of flagella on their surface; some have a single flagellum (**monotrichous**), a flagellum at each end (**amphitrichous**), clusters of flagella at the poles of the cell (**lophotrichous**), while others have flagella distributed over the entire surface of the cell (**peritrichous**). The bacterial flagella is the best-understood motility structure in any organism and is made of about 20 proteins, with approximately another 30 proteins required for its regulation and assembly.[124] The flagellum is a rotating structure driven by a reversible motor at the base that uses the electrochemical gradient across the membrane for power.[128] This motor drives the motion of the filament, which acts as a propeller.

Many bacteria (such as *E. coli*) have two distinct modes of movement: forward movement (swimming) and tumbling. The tumbling allows them to reorient and makes their movement a three-dimensional random walk.[129] (See external links below for link to videos.) The flagella of a unique group of bacteria, the spirochaetes, are found between two membranes in the periplasmic space. They have a distinctive helical body that twists about as it moves.[124]

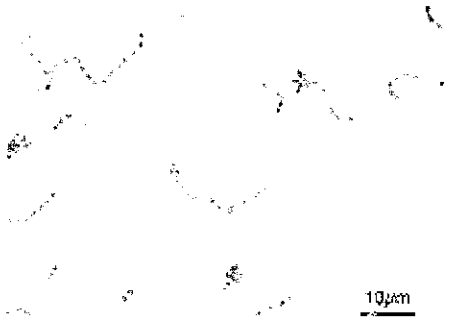
Motile bacteria are attracted or repelled by certain stimuli in behaviors called **taxes**: these include chemotaxis, phototaxis, energy taxis and magnetotaxis.[130][131][132] In one peculiar group, the myxobacteria, individual bacteria move together to form waves of cells that then differentiate to form fruiting bodies containing spores.[40] The myxobacteria move only when on solid surfaces, unlike *E. coli*, which is motile in liquid or solid media.

Several *Listeria* and *Shigella* species move inside host cells by usurping the cytoskeleton, which is normally used to move organelles inside the cell. By promoting actin polymerization at one pole of their cells, they can form a kind of tail that pushes them through the host cell's cytoplasm.[133]

Classification and identification

Main article: Bacterial taxonomy

Further information: Scientific classification, Systematics, Bacterial phyla and Clinical pathology



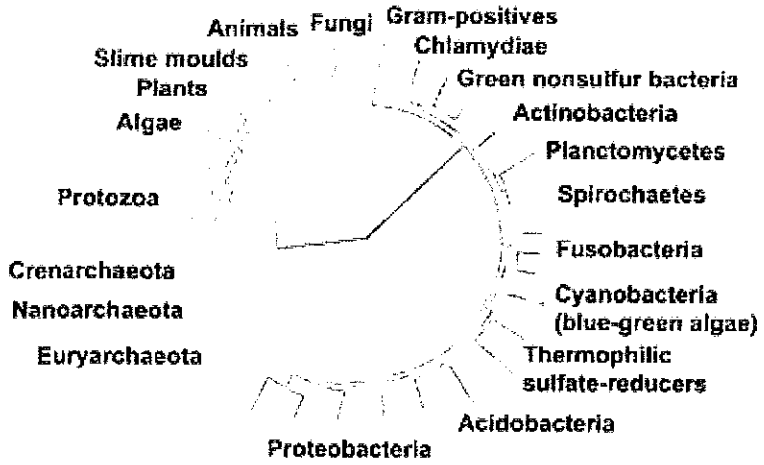
Classification seeks to describe the diversity of bacterial species by naming and grouping organisms based on similarities. Bacteria can be classified on the basis of cell structure, cellular metabolism or on differences in cell components such as DNA, fatty acids, pigments, antigens and quinones.[95] While these

Streptococcus mutans visualized with a Gram stain

schemes allowed the identification and classification of bacterial strains, it was unclear whether these differences represented variation between distinct species or between strains of the same species. This uncertainty was due to the lack of distinctive structures in most bacteria, as well as lateral gene transfer between unrelated species.[134] Due to lateral gene transfer, some closely related bacteria can have very different morphologies and metabolisms. To overcome this uncertainty, modern bacterial classification emphasizes molecular systematics, using genetic techniques such as guanine cytosine ratio determination, genome-genome hybridization, as well as sequencing genes that have not undergone extensive lateral gene transfer, such as the rRNA gene.[135] Classification of bacteria is determined by publication in the International Journal of Systematic Bacteriology,[136] and Bergey's Manual of Systematic Bacteriology.[137] The International Committee on Systematic Bacteriology (ICSB) maintains international rules for the naming of bacteria and taxonomic categories and for the ranking of them in the International Code of Nomenclature of Bacteria.

The term "bacteria" was traditionally applied to all microscopic, single-cell prokaryotes. However, molecular systematics showed prokaryotic life to consist of two separate domains, originally called *Eubacteria* and *Archaebacteria*, but now called *Bacteria* and *Archaea* that evolved independently from an ancient common ancestor.[14] The archaea and eukaryotes are more closely related to each other than either is to the bacteria. These two domains, along with Eukarya, are the basis of the three-domain system, which is currently the most widely used classification system in microbiolology.[138] However, due to the relatively recent introduction of molecular systematics and a rapid increase in the number of genome sequences that are available, bacterial classification remains a changing and expanding field.[9][139] For example, a few biologists argue that the Archaea and Eukaryotes evolved from Gram-positive bacteria.[140]

Identification of bacteria in the laboratory is particularly relevant in medicine, where the correct treatment is determined by the bacterial species causing an infection. Consequently, the need to identify human pathogens was a major impetus for the development of techniques to identify bacteria.



Phylogenetic tree showing the diversity of bacteria, compared to other organisms.[141] Eukaryotes are colored red, archaea green and bacteria blue.

The **Gram stain**, developed in 1884 by Hans Christian Gram, characterises bacteria based on the structural characteristics of their cell walls.[63] The thick layers of peptidoglycan in the "Gram-positive" cell wall stain purple, while the thin "Gram-negative" cell wall appears pink. By combining morphology and Gram-staining, most bacteria can be classified as belonging to one of four groups (Gram-positive cocci, Gram-positive bacilli, Gram-negative cocci and Gram-negative bacilli). Some organisms are best identified by stains other than the Gram stain,

particularly mycobacteria or *Nocardia*, which show acid-fastness on Ziehl–Neelsen or similar stains.[142] Other organisms may need to be identified by their growth in special media, or by other techniques, such as serology.

Culture techniques are designed to promote the growth and identify particular bacteria, while restricting the growth of the other bacteria in the sample. Often these techniques are designed for specific specimens; for example, a sputum sample will be treated to identify organisms that cause pneumonia, while stool specimens are cultured on selective media to identify organisms that cause diarrhoea, while preventing growth of non-pathogenic bacteria. Specimens that are normally sterile, such as blood, urine or spinal fluid, are cultured under conditions designed to grow all possible organisms.[95][143] Once a pathogenic organism has been isolated, it can be further characterised by its morphology, growth patterns such as (aerobic or anaerobic growth, patterns of hemolysis) and staining.

As with bacterial classification, identification of bacteria is increasingly using molecular methods. Diagnostics using such DNA-based tools, such as polymerase chain reaction, are increasingly popular due to their specificity and speed, compared to culture-based methods.[144] These methods also allow the detection and identification of "viable but nonculturable" cells that are metabolically active but non-dividing.[145] However, even using these improved methods, the total number of bacterial species is not known and cannot even be estimated with any certainty. Following present classification, there are a little less than 9,300 known species of prokaryotes, which includes bacteria and archaea.[146] but attempts to estimate the true number of bacterial diversity have ranged from 10^7 to 10^9 total species – and even these diverse estimates may be off by many orders of magnitude.[147][148]

Interactions with other organisms

Despite their apparent simplicity, bacteria can form complex associations with other organisms. These symbiotic associations can be divided into parasitism, mutualism and commensalism. Due to their small size, commensal bacteria are ubiquitous and grow on animals and plants exactly as they will grow on any other surface. However, their growth can be increased by warmth and sweat, and large populations of these organisms in humans are the cause of body odor.

Predators

Some species of bacteria kill and then consume other microorganisms, these species called *predatory bacteria*.[149] These include organisms such as *Myxococcus xanthus*, which forms swarms of cells that kill and digest any bacteria they encounter.[150] Other bacterial predators either attach to their prey in order to digest them and absorb nutrients, such as *Vampirococcus*, or invade another cell and multiply inside the cytosol, such as *Daptobacter*.[151] These predatory bacteria are thought to have evolved from saprophages that consumed dead microorganisms, through adaptations that allowed them to entrap and kill other organisms.[152]

Mutualists

Certain bacteria form close spatial associations that are essential for their survival. One such mutualistic association, called interspecies hydrogen transfer, occurs between clusters of anaerobic bacteria that consume organic acids such as butyric acid or propionic acid and produce hydrogen, and methanogenic

Archaea that consume hydrogen.[153] The bacteria in this association are unable to consume the organic acids as this reaction produces hydrogen that accumulates in their surroundings. Only the intimate association with the hydrogen-consuming Archaea keeps the hydrogen concentration low enough to allow the bacteria to grow.

In soil, microorganisms that reside in the rhizosphere (a zone that includes the root surface and the soil that adheres to the root after gentle shaking) carry out nitrogen fixation, converting nitrogen gas to nitrogenous compounds.[154] This serves to provide an easily absorbable form of nitrogen for many plants, which cannot fix nitrogen themselves. Many other bacteria are found as symbionts in humans and other organisms. For example, the presence of over 1,000 bacterial species in the normal human gut flora of the intestines can contribute to gut immunity, synthesise vitamins such as folic acid, vitamin K and biotin, convert sugars to lactic acid (see *Lactobacillus*), as well as fermenting complex undigestible carbohydrates.[155][156][157] The presence of this gut flora also inhibits the growth of potentially pathogenic bacteria (usually through competitive exclusion) and these beneficial bacteria are consequently sold as probiotic dietary supplements.[158]

Pathogens

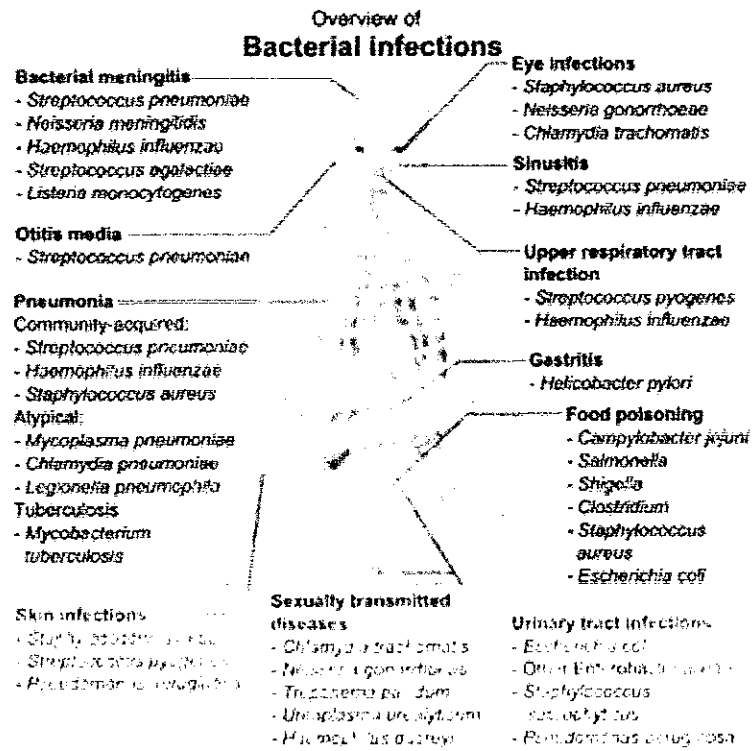
Main article: Pathogenic bacteria

Color-enhanced scanning electron micrograph showing *Salmonella typhimurium* (red) invading cultured human cells

If bacteria form a parasitic association with other organisms, they are classed as pathogens. Pathogenic bacteria are a major cause of human death and disease and cause infections such as tetanus, typhoid fever, diphtheria, syphilis, cholera, foodborne illness, leprosy and tuberculosis. A pathogenic cause for a known medical disease may only be discovered many years after, as was the case with *Helicobacter pylori* and peptic ulcer disease. Bacterial diseases are also important in agriculture, with bacteria causing leaf spot, fire blight and wilts in plants, as well as Johne's disease, mastitis, salmonella and anthrax in farm animals.

Each species of pathogen has a characteristic spectrum of interactions with its human hosts. Some organisms, such as *Staphylococcus* or *Streptococcus*, can cause skin infections, pneumonia, meningitis and even overwhelming sepsis, a systemic inflammatory response producing shock, massive vasodilation and death.[159] Yet these organisms are also part of the normal human flora and usually exist on the skin or in the nose without causing any disease at all. Other organisms invariably cause disease in humans, such as the Rickettsia, which are obligate intracellular parasites able to grow and reproduce only within the cells of other organisms. One species of Rickettsia causes typhus, while another causes Rocky Mountain spotted fever. *Chlamydia*, another phylum of obligate intracellular parasites, contains species that can cause pneumonia, or urinary tract infection and may be involved in coronary heart disease.[160] Finally, some species such as *Pseudomonas aeruginosa*, *Burkholderia cenocepacia*, and *Mycobacterium avium* are opportunistic pathogens and cause disease mainly in people suffering from immunosuppression or cystic fibrosis.[161][162]

Bacterial infections may be treated with antibiotics, which are classified as bacteriocidal if they kill bacteria, or bacteriostatic if they just prevent bacterial growth. There are many types of antibiotics and each class inhibits a process that is different in the pathogen from that found in the host. An example of



Overview of bacterial infections and main species involved.[163][164]

how antibiotics produce selective toxicity are chloramphenicol and puromycin, which inhibit the bacterial ribosome, but not the structurally different eukaryotic ribosome.[165] Antibiotics are used both in treating human disease and in intensive farming to promote animal growth, where they may be contributing to the rapid development of antibiotic resistance in bacterial populations.[166] Infections can be prevented by antiseptic measures such as sterilizing the skin prior to piercing it with the needle of a syringe, and by proper care of indwelling catheters. Surgical and dental instruments are also sterilized to prevent contamination by bacteria. Disinfectants such as bleach are used to kill bacteria or other pathogens on surfaces to prevent contamination and further reduce the risk of infection.

Significance in technology and industry

Further information: Economic importance of bacteria

Bacteria, often lactic acid bacteria such as *Lactobacillus* and *Lactococcus*, in combination with yeasts and molds, have been used for thousands of years in the preparation of fermented foods such as cheese, pickles, soy sauce, sauerkraut, vinegar, wine and yogurt.[167][168]

The ability of bacteria to degrade a variety of organic compounds is remarkable and has been used in waste processing and bioremediation. Bacteria capable of digesting the hydrocarbons in petroleum are often used to clean up oil spills.[169] Fertilizer was added to some of the beaches in Prince William Sound in an attempt to promote the growth of these naturally occurring bacteria after the 1989 *Exxon Valdez* oil spill. These efforts were effective on beaches that were not too thickly covered in oil. Bacteria are also used for the bioremediation of industrial toxic wastes.[170] In the chemical industry, bacteria are most important in the production of enantiomerically pure chemicals for use as pharmaceuticals or agrichemicals.[171]

Bacteria can also be used in the place of pesticides in the biological pest control. This commonly involves *Bacillus thuringiensis* (also called BT), a Gram-positive, soil dwelling bacterium. Subspecies of this bacteria are used as a Lepidopteran-specific insecticides under trade names such as Dipel and Thuricide.[172] Because of their specificity, these pesticides are regarded as environmentally friendly, with little or no effect on humans, wildlife, pollinators and most other beneficial insects.[173][174]

Because of their ability to quickly grow and the relative ease with which they can be manipulated, bacteria are the workhorses for the fields of molecular biology, genetics and biochemistry. By making mutations in bacterial DNA and examining the resulting phenotypes, scientists can determine the function of genes, enzymes and metabolic pathways in bacteria, then apply this knowledge to more complex organisms.[175] This aim of understanding the biochemistry of a cell reaches its most complex expression in the synthesis of huge amounts of enzyme kinetic and gene expression data into mathematical models of entire organisms. This is achievable in some well-studied bacteria, with models of *Escherichia coli* metabolism now being produced and tested.[176][177] This understanding of bacterial metabolism and genetics allows the use of biotechnology to bioengineer bacteria for the production of therapeutic proteins, such as insulin, growth factors, or antibodies.[178][179]

History of bacteriology

Bacteria were first observed by Antonie van Leeuwenhoek in 1676, using a single-lens microscope of his own design.[180] He called them "animalcules" and published his observations in a series of letters to the Royal Society.[181][182][183] The name *Bacterium* was introduced much later, by Christian Gottfried Ehrenberg in 1828.[184] In fact, *Bacterium* was a genus that contained non-spore-forming rod-shaped bacteria,[185] as opposed to *Bacillus*, a genus of spore-forming rod-shaped bacteria defined by Ehrenberg in 1835.[186]

Antonie van Leeuwenhoek, the first microbiologist and the first person to observe bacteria using a microscope.

Louis Pasteur demonstrated in 1859 that the fermentation process is caused by the growth of microorganisms, and that this growth is not due to spontaneous generation. (Yeasts and molds, commonly associated with fermentation, are not bacteria, but rather fungi.) Along with his contemporary Robert Koch, Pasteur was an early advocate of the germ theory of disease.[187] Robert Koch was a pioneer in medical microbiology and worked on cholera, anthrax and tuberculosis. In his research into tuberculosis, Koch finally proved the germ theory, for which he was awarded a Nobel Prize in 1905.[188] In *Koch's postulates*, he set out criteria to test if an organism is the cause of a disease, and these postulates are still used today.[189]

Though it was known in the nineteenth century that bacteria are the cause of many diseases, no effective antibacterial treatments were available.[190] In 1910, Paul Ehrlich developed the first antibiotic, by changing dyes that selectively stained *Treponema pallidum* — the spirochaete that causes syphilis — into compounds that selectively killed the pathogen.[191] Ehrlich had been awarded a 1908 Nobel Prize for his work on immunology, and pioneered the use of stains to detect and identify bacteria, with his work being the basis of the Gram stain and the Ziehl–Neelsen stain.[192]

A major step forward in the study of bacteria was the recognition in 1977 by Carl Woese that archaea have a separate line of evolutionary descent from bacteria.[193] This new phylogenetic taxonomy was based on the sequencing of 16S ribosomal RNA, and divided prokaryotes into two evolutionary domains, as part of the three-domain system.[194]